BIOLOGY

A Textbook for Higher Secondary Schools

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BIOLOGY

A Textbook for Higher Secondary Schools

SECTION 3

The Diversity of Animal Life

Edited by
P. MAHESHWARI F.R.S.
and
MANOHAR LAL

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National Council of Educational Research and Training

ACKNOWLEDGEMENT

The National Council of Educational Research and Training has undertaken a major programme to prepare model textbooks in different subjects for the school curriculum. For this purpose, the Council has set up a Central Committee for Educational Literature to guide and direct the programme. Panels of specialists have been set up by the Central Committee to develop curricula and to write textbooks, teachers' resource books and other materials on school subjects.

The Biology Textbook Panel under the Chairmanship of Prof. P. Maheshwari, Head of the Department of Botany, Delhi University, has been developing for the last two years, curriculum, syllabus and textbook of biology for higher secondary classes.

The biology curriculum and text material were reviewed by practising teachers and science educators before they were finalised. Section 1 of the textbook was published in September, 1964 and since then, it has been adopted by the higher secondary schools affiliated to the Central Board of Secondary Education. The present publication deals with Section 3 of the series devoted to 'The Diversity of Animal Life'.

The National Council wishes to thank Prof. P. Maheshwari, the Chairman, and members of the Biology Panel for their valuable contribution to the preparation of the biology books.

The remaining four sections of the textbook will be published in the course of 1965. It is also proposed to publish one single volume containing all sections together.

The National Council invites suggestions from teachers and science educators on the biology series.

L. S. CHANDRAKANT
Joint Director
National Council of Educational
Research and Training

New Delhi.
August 1965

Foreword

FOR several years I have seriously felt the lack of good school and college textbooks on biology Most of the existing books emphasize only the descriptive aspects of the subject, largely ignoring the newer and more fundamental concepts. This is, in part at least, responsible for adversely influencing the public image of biology and for relegating it to a subordinate position in the list of sciences No thinking person can doubt that biology profoundly affects the life of all human beings and its study is one of the most essential requisites of every responsible and intelligent citizen. Further, the study of biology must begin right in the school as an integral part of any course in science instead of being postponed to the college or university stage. The pupil's choice of the subject of his future study is determined, to a large extent, by the courses he has attended in school and by the type of text matter presented to him at this stage.

Recognizing the above facts, I readily accepted the invitation of the National Council of Educational Research and Training to act as Chairman of the Panel set up to prepare a new and modern textbook suited for use in Indian Secondary Schools.

This publication is the third section of the textbook. It deals with 'The Diversity of Animal Life' spread over 14 chapters. The subsequent sections will be brought out in due course and when they are all ready the book will also be produced as a single bound unit.

It may be noted that there are several ways of approaching the subject of biology, each having its own merits and demerits. The editors and members of the Panel are convinced that a wide acquaintance with a number of different kinds of organisms, their activities, their habits and their tissues and organs, is essential and basic to the understanding of the general concepts of evolution, ecology, heredity, and cell physiology. This approach, in their opinion, combines not only the pedagogical advantage of proceeding from the known to the unknown but also prevents students from getting lost in the intricacies of the more advanced aspects of biology.

Although evolution is treated separately in two chapters, an attempt has nevertheless been made to acquaint the student with this all pervasive principle during his study of the world of life. Biological phenomena common to plants and animals have been discussed together as far as possible. Technical terms have been kept down to the minimum except when their use is believed to contribute to easier communication and understanding Important biological discoveries have been dealt with in a historical perspective to give an idea of how science progresses

It has been our objective to present the subject in an understandable, stimulating and instructive fashion We shall appreciate receiving comments, criticisms and suggestions. These will be taken into account in bringing out a revised version of the book

The original drafts of the chapters in the book were contributed by several persons whose names are given below in alphabetical order Dr R.N. Chopra, Reader in Botany, University of Delhi, Smt. E Gonzalves, Biology Department, St Xavier's College, Bombay; Prof N.B. Inamdar, Head of the Department of Zoology, Institute of Science, Bombay, Prof B.M Johri, Department of Botany, University of Delhi, Dr. G.N. Johri, School of Studies in Zoology, Vikram University, Ujjain, Dr. L N Johri, Reader in Zoology, University of Delhi, Dr. M S Kanungo, Reader in Zoology, Banaras Hindu University, Dr. Manohar Lal, Department of Botany, University of Delhi, Dr S C. Maheshwari, Reader in Botany, University of Delhi; Dr. L.P. Mall, Reader in Botany, Vikram University, Ujjain; Prof. R D. Misra, Head of the Department of Botany, Banaras Hindu University; Dr. H.Y. Mohan Ram, Reader in Botany, University of Delhi, Prof. M.R N Prasad, Department of Zoology, University of Delhi , Dr. B. Tiagi, Reader in Botany, University of Rajasthan, Jaipur, and Dr H S Vishnoi, Department of Zoology, University of Delhi

There was naturally a good deal of editing work to be done in order to bring the manuscripts into a form suitable for publication, and to add the illustrations to make the text understandable. In this I was ably assisted by my colleague Dr. Manohar Lal whose help was invaluable in looking after the large volume of work associated with such a project.

I was receiving the ungrudging help of several other persons among whom special mention must be made of Drs G S. Paliwal, Sipra Guha and Man Mohan Johri of the Botany Department, Delhi University, who looked after much of the day to day routine and the reading of the proofs. Prof Ralph Buchsbaum of the Department of Zoology, University of Pittsburgh, and Dr. R Will Burnett of the Teachers College Columbia University Team in India critically read through Section 3 on animals, Prof. W N Stewart of the Department of Botany, University of Illinois, gave many useful comments on Section 2 dealing with plants, Dr. S.S. Sehgal extended valuable help in preparing and checking up illustrations for Section 3 ; and Dr S.C Maheshwari of the Department of Botany, University of Delhi, read Section 4 on physiology Two school teachers—Shri S.M Sharma of the Harcourt Butler Higher Secondary School, New Delhi, and Miss Katherine Bolton formerly of St Thomas Girls' Higher Secondary School, New Delhi,—went through some of the chapters and offered several helpful suggestions. The help received in the form of photographs and other copyright material is acknowledged in the captions Figures 26 9, 27 6 and 28 1 have been taken from *Nature*, a part of the Macdonald Illustrated Library

I must add that the book might never have seen the light of the day but for the constant help and generous co-operation of the following officers of the National Council of Educational Research and Training Shri L S. Chandrakant, Joint Director, Shri P N Natu, Secretary, Dr R.N Rai, Head of the Department of Science Education, Smt S. Doraiswami former Chief Publication Officer, Smt A Krishnaswami, Chief Publication Officer, and Shri S. Doraiswami, Secretary of the Biology Panel.

P MAHESHWARI
Chairman, Biology Panel,
National Council of Educational Research and Training

Delhi
August, 1965

Preface

IN the midst of the present remarkable achievements in rocketry, nuclear energy, synthetic plastics and fibres, and exploration of space, the study of living organisms, their functions and their importance is frequently minimized or overlooked It is often forgotten that the primary aim of science, apart from the satisfaction of intellectual curiosity, is the survival and welfare of man. Nothing has contributed more to human welfare and to the very emergence of man from his early animal behaviour, than the knowledge of plants, animals, and his own body. It is said that there are four chief ravages of humanity—diseases, wars, famine, and now over-population. From man's point of view, therefore, biology is the most fundamental and important of all the sciences. It affects vital state policies on matters like conservation of natural and human resources, radiation experiments, population control, quarantine and health programmes. Biology also helps us answer such personal questions as: what determines sex, who is responsible for the sex of the baby, the mother or the father; how are twins born, why do babies resemble their parents; how do we acquire immunity against a disease, why do we become enfeebled in old age, how are plants and animals interdependent, and so on. Sanitation, nutrition, pest control, and other attributes of intelligent citizenship, all require a biological background. Finally, biology—a study of the unity as well as the diversity of plant and animal life—is an intellectually enlightening and aesthetically satisfying experience. Indeed, in view of its importance in everyday life, biology should be made a compulsory subject for all school boys and girls. For all this we need adequate textbooks which present the subject in a satisfactory manner keeping in view the needs of the country for which the book is written. The present book is an attempt in that direction.

Should Botany and Zoology be Taught as Separate Subjects? The book adopts, in so far as possible, a common treatment of plants and animals and attempts to emphasize the basic unity in the organization and functioning of living matter. This might appear at first sight to be rather undesirable to those who are used to teaching botany and zoology as separate, well-defined subjects with little or no similarity. They might indeed question the commonness between a cow and a *neem* tree. To such critics we owe an explanation right in the beginning

In the nineteenth century there was a tendency towards compartmentalization of subjects but the insight into the life processes acquired in the past 50 years has shown how these compartments merge into each other. Recent work on cell physiology with the newer techniques of biochemistry and biophysics has particularly called attention to a basic commonness between plants and animals This common ground also extends into the fields of genetics, cytology, evolution, physiology and electron microscopy. There is no reason why at the higher secondary stage the student should not be apprised of these broadening horizons So far as some other aspects are concerned, the book still retains separate sections on plants and animals It may be added that in English and American schools a composite biology course has been in use for the last 10 to 15 years and some universities too have recently begun to offer similar courses at the B Sc level.

Even at the research level, many well-known laboratories in the U.K and the U.S.A have a common unit for work on both plants and animals If we are to train the younger generation for successful careers in biological research, it is necessary to orient our school courses in such a way that they get the right perspective of the subject It may also be pointed out that the school biology course would be the only one which many of our boys and girls will ever attend in their life

Biology in the Twentieth Century The nineteenth century biologists concerned themselves mainly with the morphology and anatomy of plants and animals While this was natural, the subject has undergone much change in its content and character in the twentieth century This has been made possible largely by the availability of new techniques of chemistry and physics although many milestones have also been laid purely by keen observation and logical analysis. The rediscovery of Mendel's laws of heredity infused new interest into the field of genetics and the mechanism of inheritance was firmly established Artificial means of inducing mutations in plants and animals were discovered and the genes responsible for the expression of a particular character were pin-pointed. Electron microscopy, ultracentrifugation, spectrophotometry and other techniques have further unravelled the intricate machinery of the living cell and these studies have now gone as far as the isolation and artificial synthesis of the hereditary substance-DNA. The study of enzymes, which was a minor discipline in the last century, has grown into a vast area of research Our knowledge of vitamins, hormones and antibiotics is also a gift of the present century biology An understanding of the mechanism of nerve action, brain functioning, photosynthesis, respiration and a host of other physiological processes is also derived from the researches of the last 40 years. To this list may be added the still more recent disciplines like virology, radiation and space biology, the cure for cancer and heart diseases, and finally the attempts to synthesize life itself !

Thus, the emphasis has largely shifted from a descriptive and morphological treatment to the functional aspects. It is apparent that if we continue to train our students only in nineteenth century biology, as indeed is being done in most of our schools and colleges, they will find themselves unsuited to the future needs of the scientific world.

The Need For Change One factor which makes the existing course rather dull is that its contents are mostly or entirely descriptive We think that the morphological part must still form the basis of biology and has to be done well, but this cannot be the only part, and that physiology, ecology, evolution, the interrelations between plants and animals, and the role of biology in human life are subjects that cannot be left out of consideration. A large fund of biological information acquired during the present century finds no mention in most Indian texts which also do not provide any information about the interdependence of plants and animals. Indeed, many of the existing books are as much as 50 years behind current biological thought It is perhaps true that some aspects of biology, involving a rather intensive knowledge of chemistry and physics, are too advanced and complicated to be understood by the school student. However, recent tests on the learning potential of young students have clearly shown that the general principles of physiology and genetics can be effectively taught provided a simple and popular approach is adopted and there is some demonstration material for illustration For instance, problems like what happens in photosynthesis, or respiration, or how living organisms respond to external and internal stimuli, elicit greater interest in the minds of students than learning the characters of a family of plants or describing the pectoral girdle of frog Similarly, on the practical side, the young student will take much greater interest in experimenting on the digestion of starch by an enzyme than in sketching the shapes of leaves and bones. It would be appalling if a school student should get the impression that biology is nothing more than cutting up frogs and collecting hay, or just a system of naming plants and animals in an unfamiliar language

It is sometimes argued that our textbooks are already encyclopaedic and that it is hardly possible to add more material in view of the time at the disposal of the students. This no doubt poses some difficulty because scientific knowledge is doubling itself every 10 to 15 years. Indeed, the twentieth century has provided far more scientific information than the last 5000 years This knowledge must naturally be incorporated into broad biological concepts so as to become a part of our everyday thinking To do this one has obviously to cut out certain portions. Such facts as are only of an additive nature or matters of unnecessary detail must therefore be pruned and the dead wood removed here and there. To take a specific instance, a student need not spend too much time in learning the variations in the organization of flowers or vertebrae Since everything cannot be taught at the school stage, a judicial balance has to be struck between depth and breadth

Another surprising factor is that in the past the courses in India in this subject have virtually excluded the study of human biology While the students have been studying in detail the various types of roots and stems as well as the smallest bones of a frog, they remained wholly ignorant of their own body.

The Book The book has been divided into seven, more or less independent sections. In the first section the student is introduced to the subject matter of science, particularly biology, and the characteristics of the living matter A glimpse of the variety of plant and animal life prepares the student for a more detailed study of these forms in the second and third sections The fourth section treats the main physiological processes in animals and plants in a simple way. The fifth is devoted to a comparative account of the different modes of reproduction in the plant and animal kingdoms Heredity, evolution and ecology form the sixth section of the book. The epilogue to the book covers topics like human diseases, interdependence of plants and animals and the role of biology in human welfare

We have much pleasure in presenting this book to the students and teachers of the Higher Secondary Classes and shall try to incorporate any suggestions for improvement in the next edition

Department of Botany
University of Delhi.

Editors P. MAHESHWARI
MANOHAR LAL

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SECTION 3

The Diversity of Animal Life

Introduction

HAVING already obtained some acquaintance with the major groups of animals in Section I, you are now ready for gaining a broader understanding of the diversity of animal life together with the working of the animal body including your own.

As we did in the case of plants (Section II), here too we shall begin with the animals with which you are most familiar, i e the vertebrates. A detailed study of the main systems in frog, substantiated with many dissections in the practical class, will lead you to having a better insight into the working of the animal body

During your parade of the animal kingdom, you will perceive a few broad trends in the evolutionary story of animals The most primitive are the unicellular protozoans which nevertheless exemplify diverse forms and habits of life possible within the limits of a single cell The aggregation of many cells, as in all metazoans, offered a greater opportunity for further differentiation of the body resulting in the formation of an increasing number of organs with greater and greater complexity or specialization. In the lowest of the metazoa—the sponges and coelenterates—there is a simple central cavity for the digestion of food and some other functions Later, the digestive cavity takes a definite form and in still higher types it becomes associated with some accessory organs such as the pancreas, liver and so on

The metazoan body develops from a single cell, the fertilized egg or zygote This cell divides repeatedly to form a hollow ball of cells This ball undergoes an invagination to form a cup-like structure having two layers of cells The outer layer is called the **ectoderm** and the inner, the **endoderm.** In coelenterates even the adult body consists of only these two layers (Fig. 1). Such animals are, therefore, termed **diploblastic** (Gk *diploos*=double, *blastos*=bud—i.e. having two distinct germinal layers) The complex organization in higher forms has resulted from the appearance of a third germinal layer, the **mesoderm,** between the ectoderm and endoderm Each of these produces many tissues resulting in the formation of a variety of organs Animals, whose adult organs are derived from the three germinal layers, are termed **triploblastic** (Gk *triploos*=triple; *blastos*=bud). At the same time there appears a second cavity, the coelome, between the body wall and the digestive canal. This gives the well-known 'tube within a tube' plan of the body, characteristic

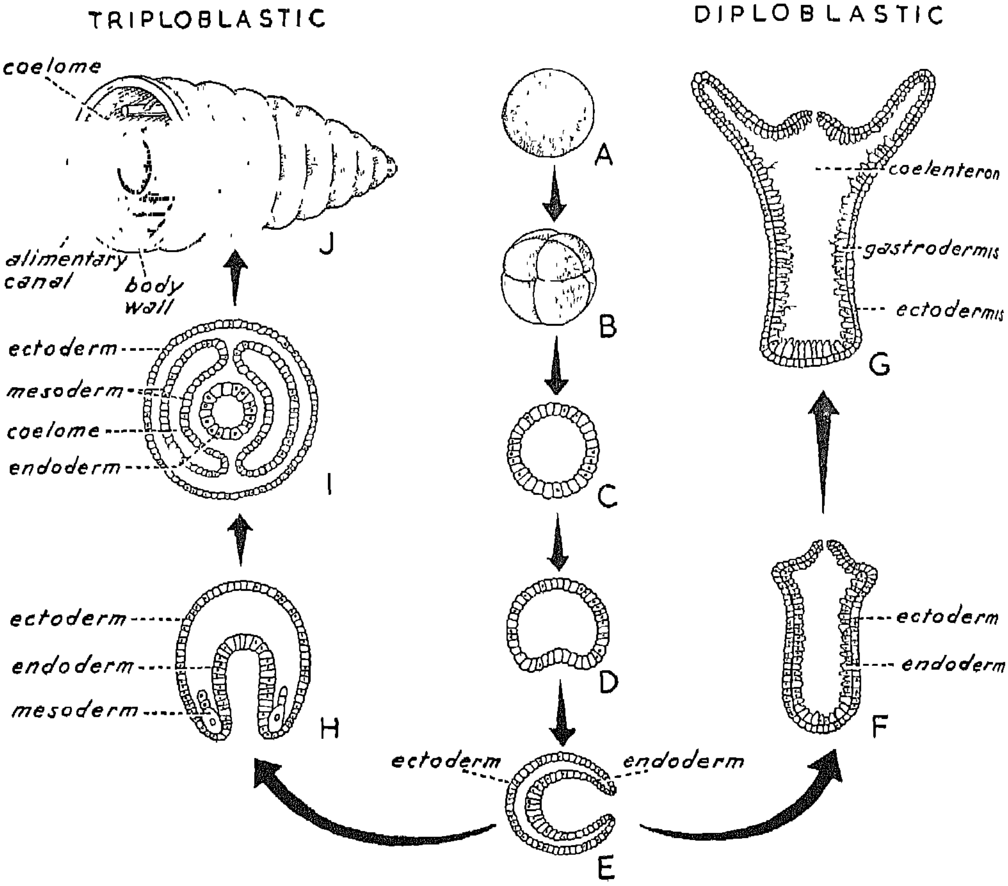

Fig. 1. The development of the diploblastic and triploblastic condition in the multicellular animals.

of all metazoans from the Nemathelminthes onwards.

In describing the external forms and shapes of animals, it will be helpful to understand certain basic terms. The external form is generally described by saying whether an animal is symmetrical or asymmetrical. A **symmetrical** animal is one which can be divided into similar halves (mirror images) by one or more imaginary cuts passing through its centre. You would at once appreciate that most animals do have some kind of symmetry. However, an animal like the amoeba has no constant form. No cutting line would result in identical halves. Such animals are said to be **asymmetrical** (Fig. 2). Most animals, including man, show a **bilateral symmetry**. The bodies of such animals can be divided by only one vertical plane into right and left halves which are mirror images of one another. In most bilateral animals one side of the body always keeps upwards while the other faces the ground. The former is called the **dorsal** surface (L *dorsum*=back), and the latter is called the **ventral** surface

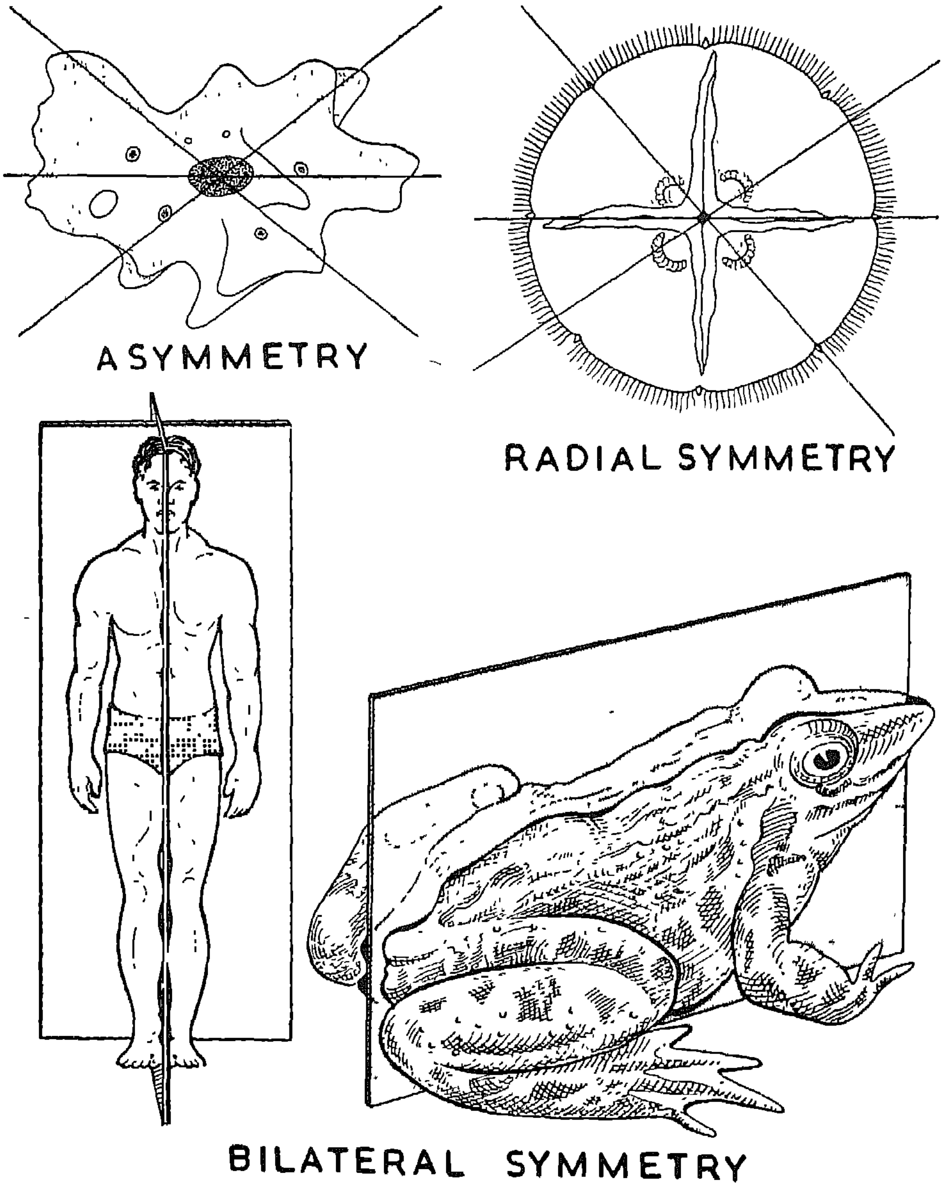

Fig. 2. Three types of symmetry commonly met with in animals.

(L. *venter*=belly). Between the dorsal and ventral surfaces, on each side is the **lateral** surface (L. *latus*=side). The end of the body which is kept forward during locomotion is the anterior or head end, and the opposite is the posterior or tail end.

A cylindrical or circular animal is said to have **radial symmetry** since any longitudinal cut along the diameter would yield mirror images. A jellyfish, for instance, is radially symmetrical (Fig. 2). In certain other organisms there are two radial planes of symmetry at right angles to each other. Each plane gives identical halves but the halves obtained with planes along one direction are not similar to those obtained with planes along the other direction which is at right angles to the first. The limbs (arms and legs), wings and fins are the **appendages** of the main body. The part of an appendage or organ, which lies towards the central axis of the body such as the upper arm and the thigh is said to be **proximal,** whereas that farther from the central axis such as the hand and the foot is said to be **distal.**

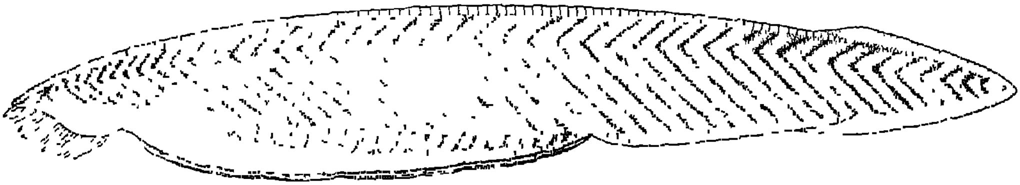

Fig. 3. ***Amphioxus*, a primitive marine protochordate in which the notochord is not replaced by a backbone.**

The Vertebrates and Their Classification

You would recall that the entire animal kingdom is often separated into two divisions the invertebrates or animals without a backbone, and the vertebrates or animals with a backbone. The invertebrates (from amoeba to starfish) are too diverse to be included in a single group and hence these are divided into several distinct phyla which will be dealt with in the second part of this section. The vertebrates (fishes, frogs, snakes, birds, monkeys, etc.) are also quite diverse in their general habits and structure and yet remarkably similar in having certain basic characters. Most important among these is the presence of a backbone—the principal supporting skeleton lying in the mid-dorsal axis of the body. The backbone is composed of a series of bones called the vertebrae, and hence the name Vertebrata. In the embryonic stages, however, all the vertebrates have another structure in place of the backbone. This is called the **notochord.** It is an axial rod of turgid cells. In later development a series of vertebrae develop around the notochord.

There are a few forms which never develop a true backbone but possess only a notochord. For example, the fish-like 'lancelet' (Fig. 3) retains a notochord throughout its life. Certain forms like the ascidians (Fig. 4) possess the notochord only in the tail region in their larval stages, and even this is lost in the adults without developing into any backbone. All these animals having a notochord but no backbone are called the protochordates.

The protochordates and vertebrates together constitute the phylum Chordata. They are distinguished from the non-chor-

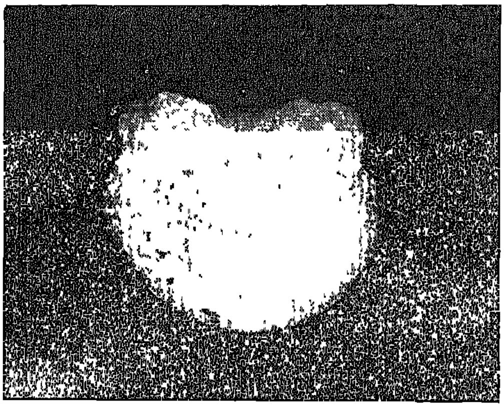

Fig. 4. *Herdmania*, **another protochordate, the adult form of which has neither notochord nor backbone.**

dates by the following characters (1) there is a dorsal skeletal axis or notochord which is replaced by a backbone in the vertebrates, (2) there is a hollow, tubular nerve cord (spinal cord) lying in the mid-dorsal plane, just above the notochord or enclosed in the backbone; (3) paired gill slits are present on the sides of the pharynx. They are functional throughout life in the lower chordates and fishes. In the higher forms the gill slits disappear during embryonic development.

The above characteristics of the chordates are indicated in figure 5. In addition to these the vertebrates in general possess a chambered heart placed ventrally, and two pairs of appendages (fins or limbs).

The vertebrates are usually divided into seven classes—Cyclostomata, Chondrichthyes, Osteichthyes, Amphibia, Reptilia, Aves and Mammalia. The first three of these classes are usually grouped together under Fishes, and the remaining four under Tetrapoda (animals bearing four legs).

Class CYCLOSTOMATA (Gk. *kyklos*=circle, *stoma*=mouth) Hagfishes and lampreys. These have a large circular mouth-funnel without any jaws, and are therefore also called the Agnatha (Gk *a*=without, *gnathos*=jaw).

Class CHONDRICHTHYES (Gk. *chondros*=cartilage, *ichthys*=fish). Sharks and rays. These fishes possess a cartilaginous skeleton and are found only in the sea.

Class OSTEICHTHYES (Gk *osteon*=bone; *ichthys*=fish) 'Rohu', 'katla', etc,

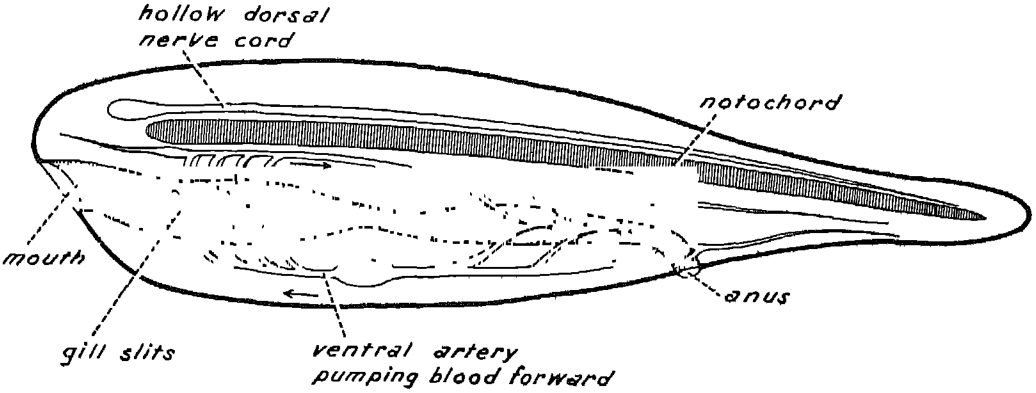

Fig. 5. Diagrammatic representation of the primary characteristics of chordates, as seen in the gill breathers. After T.H Eaton Jr., *Comparative Anatomy of the Vertebrates*, Harper and Brothers, Publishers, New York, 1951.

This class includes fishes having a skeleton made of bones. They inhabit both sea and freshwater.

Class AMPHIBIA (Gk. *amphi*=both, *bios*=life). Salamanders, frogs and toads They live both on land and in freshwater. They have a smooth skin without any external scales.

Class REPTILIA (L. *reptare*=to creep). Lizards, snakes, tortoises and crocodiles The animals belonging here have a dry and scaly skin.

Class AVES (L. *avis*=bird) Pigeons, kites, crows, etc These have a pair of wings for flying and their body is covered with feathers.

Class MAMMALIA (L *mamma*= breast). Horse, cow, camel, monkey, man, etc. These are hairy animals which suckle their young ones.

CHAPTER 24

Fishes

FISHES are very familiar aquatic animals. However, some names, such as the jellyfish, crayfish and starfish are erroneously used for many kinds of aquatic animals, other than the true fishes. Many fishes are important articles of our food. Considerable attention is, therefore, being paid to increase fish-production

General Characters

Most fishes have a spindle-shaped body There is a head, a trunk and a tail but no neck. The skin is covered with scales which may be large and overlapping as in 'rohu' or very minute and imbedded in the skin, as in sharks. The scales may be entirely absent, as in 'singhara'. The fishes have two pairs of fins (called pectoral and pelvic fins) corresponding to the fore-limbs and hind-limbs of higher vertebrates. They also have unpaired median fins along the back, belly and tail (Fig 24.1).

The mouth is large and is situated at or very close to the front tip of the head. The jaws are provided with pointed, conical teeth. There are no eyelids and no external ears A groove, called the lateral line, runs along each side of the body from head to tail. It acts as a sense organ for perceiving pressure or currents in the surrounding water. The two nostrils are used for smelling only The sense of smell is quite sharp in fishes.

Fishes breathe by means of gills which are situated on either side just behind the head. In most cases the gills are covered by a bony plate called the gill cover or operculum. In some, there is no gill cover and the gills lie inside a series of open pouches whose external openings are called the gill-slits. Each gill carries numerous thin, thread-like gill filaments which are richly supplied with blood capillaries (Fig.

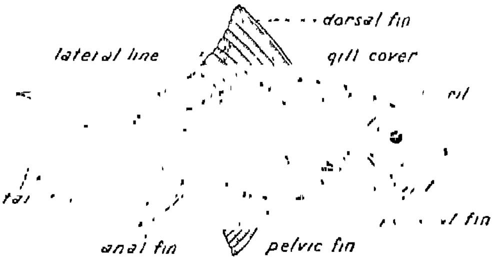

Fig. 24.1. The external features of the common Indian carp (*Labeo calbasu*). After T.J. Parker, W N Parker, B.L. Bhatia and M A Moghe, *An Elementary Text-Book of Zoology for Indian Students*, Macmillan & Co, Ltd., London, 1957.

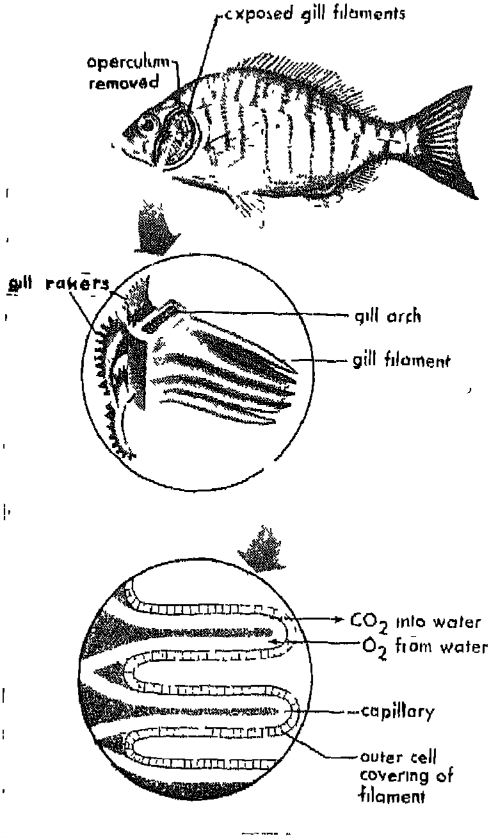

Fig. 24.2. The gills of a fish and their role in respiration. From *BSCS, Molecules to Man*, Houghton Mifflin Company, Boston, 1963

24.2) The animal takes in water through the mouth and passes it out through the gill slits. Thus the water flows over the surface of gills and the oxygen dissolved in it diffuses into the gill filaments At the same time the carbon dioxide passes out into the water. When a fish is taken out of water, the gill filaments stick to each other. There is no flow of water over them and the fish dies of oxygen starvation. Only a few fishes have lungs, they can come out of water and breathe air.

The internal organs of fishes are much simpler than those of the higher vertebrates. It will perhaps surprise you to know that the heart in a fish never receives or pumps oxygenated blood There is a single auricle and a single ventricle The auricle receives deoxygenated blood from all parts of the body and sends it into the ventricle which then pumps the whole of it into the gills for oxygenation From the gills the oxygenated blood is distributed to the body.

Most fishes breed by laying eggs (**oviparous**) but others like sharks bear their young alive (**viviparous**).

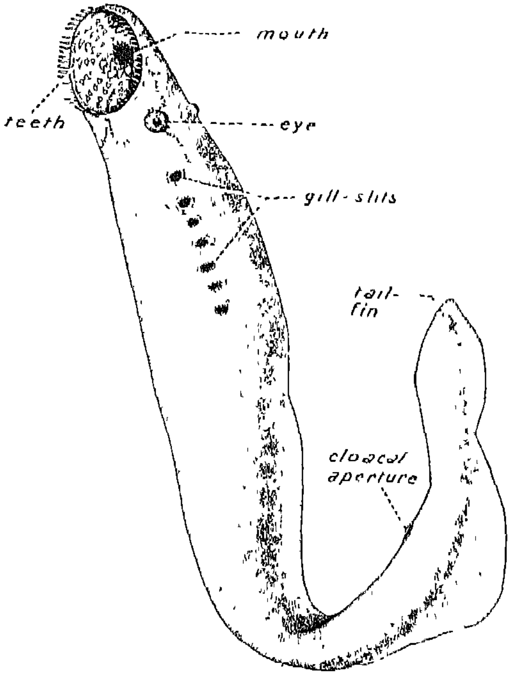

Fig. 24.3. Lamprey, a jawless fish-like vertebrate. With a sucking funnel around its mouth it sucks blood from other fishes. Note the hook-like teeth on the sucker.

Examples of Common Fishes

The lamprey (Fig. 24.3) has a long snake-like body. It has no jaws, scales or the paired fins. In place of jaws it possesses a large circular funnel-shaped mouth with horny teeth. It is a serious enemy of the other fishes. It attaches its funnel-shaped mouth to the side of a fish, makes a hole with its tongue and sucks the blood or at times even the internal organs of the victim. It is found in the sea in the colder regions of the northern hemisphere.

The sharks and rays (Fig 24.4) are marine cartilaginous fishes. Their skeleton is made of cartilage, there being no bone at all. The gill slits are distinct and there is no gill cover. The tiny scales with pointed ends are always imbedded in the skin. Most of these do not lay eggs but give birth to young ones. The dogfish found along the Indian coast is one of the smaller sharks. Some sharks may be as much as 10 metres long and weigh more than 2,000 kilograms. The sawfish with a long projecting saw-toothed rostrum, is also a type of shark found in the Indian seas. All the sharks are active swimmers.

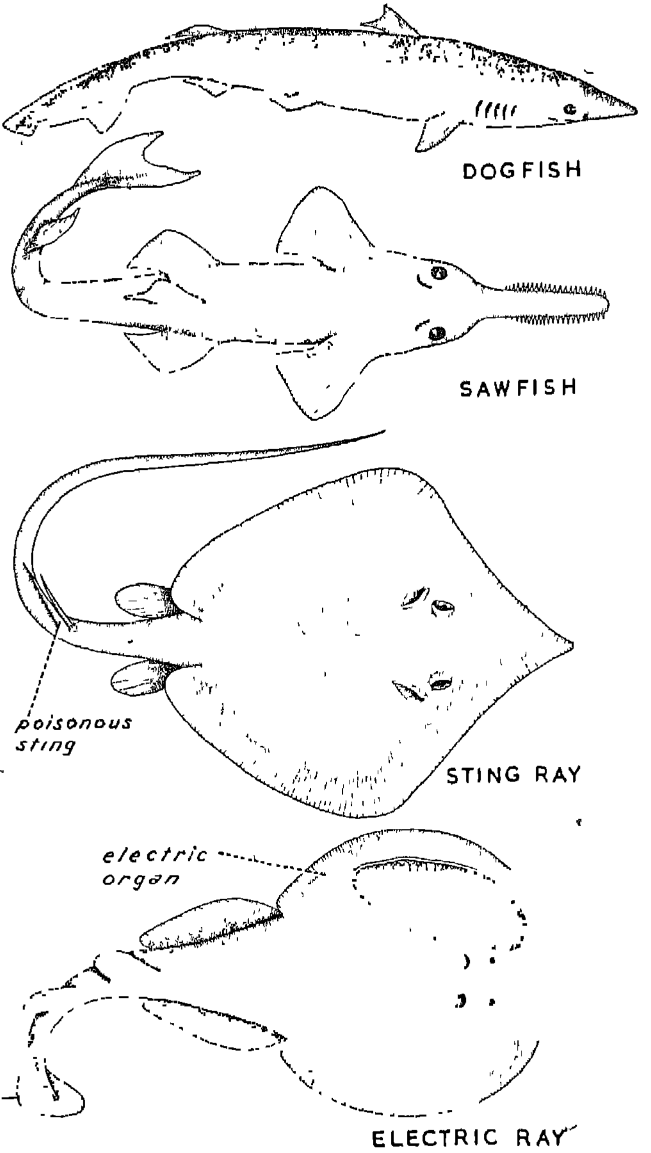

Fig. 24.4. The cartilaginous fishes—sharks (the first two) and rays (the last two). One of the electric organs in the electric ray has been exposed.

The rays have a dorso-ventrally flattened body. Their tail is usually long and whip-like. The sting ray carries a poisonous sting on its tail. The electric ray has an organ with which it can give a fairly severe electric shock. The rays live mainly at the bottom of the sea.

Most of our food fishes are actually the bony fishes. 'Rohu', 'mrigal', 'katla', 'kalbasu', 'malli', 'goonch' and 'singi' are our commonest freshwater food fishes. Pomfret, mackerel, Indian salmon, and Bombay duck are some of our common marine food fishes Their skin is either naked or covered with overlapping scales. A gill cover is always present. Usually they have a gas-filled swim-bladder in their body. By increasing or decreasing the amount of gas in the bladder, they can balance themselves at any depth in water.

Some of the bony fishes are very strange animals (Fig. 24 5). The sea horse has a curious shape with its head resembling that of a horse. It swims in an upright position. Its tail can coil round marine plants to give it a support. During mating the female sea horse passes her eggs into a special brood pouch located on the belly of the male. The flying fish has a pair of large, flat, wing-like pectoral fins with

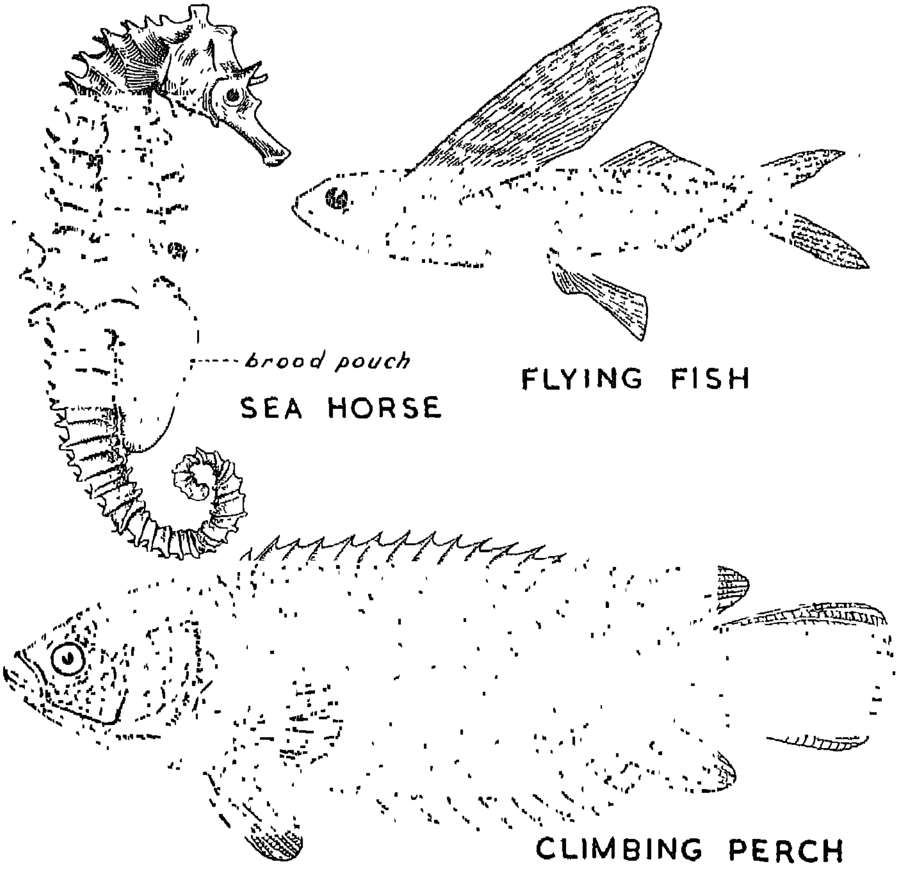

Fig. 24.5. Some curious forms of bony fishes. The male sea horse (*Hippocampus*) **carries the fertilized eggs in its brood pouch until they are hatched. The flying fish** (*Exocoetus*) **can glide in the air for some distance. The climbing perch** (*Anabas*) **cannot climb trees but it can move on land by means of spines on its gill cover and ventral fin.** From various sources.

which it can glide in the air close to the surface of water for several hundred metres. Both sea horse and flying fish occur in the Indian seas. The climbing perch or 'koi' often comes out of water and moves on land with its spiny gill cover and ventral spiny fin Its gill chamber has, in addition to the gills, a special organ designed to respire in the free air. This fish is common in pond waters all over Asia.

Migration of Fishes

Some of the fishes normally live in the sea but travel hundreds of kilometres up in the rivers to breed. For example, an estuarine fish called 'hilsa' travels up the Ganga during floods for spawning. The famous European migratory eel (Fig 24 6) and some others show a reverse behaviour. They swim in large groups thousands of kilometres from the European rivers to the North Atlantic Ocean for breeding. After laying eggs both the males and females die, and the young ones instinctively travel to their parents' home. Biologists study the migratory routes of fishes by marking them with metallic and plastic tags.

Economic Importance

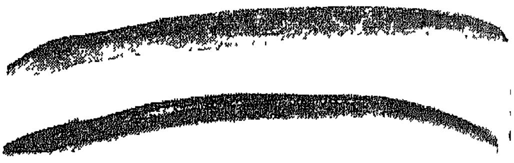

Fig. 24.6. The migratory eels live in freshwater but go to the ocean to breed. Their cylindrical body looks more like a snake than a fish.

All over the world fishes are caught for food and commercial products. Oils are obtained from the livers of shark, cod, halibut and other fishes. These are very rich in vitamins A and D, and find a great medicinal use. Shark fishing is an important industry along the Indian coast. Shark flesh is coarse and is eaten by poor people. Shark fins are used to prepare glue and gelatin. The dried rough skin of sharks is called shagreen and is used as a polisher.

Some fishes kill harmful aquatic insects such as mosquito larvae. Sport fishing or angling is a delightful recreation. Maintaining aquaria with beautiful and coloured fishes is an interesting hobby of many people.

SUMMARY

Fishes are easily identified by the presence of scales, fins and gills. They have no eyelids and external ears. They are fully adapted for living in water and breathing by gills Some fishes have lungs for aerial respiration There is a vast variety of form and colour in fishes

Lampreys are without jaws, scales or paired fins The cartilaginous fishes have a cartilaginous skeleton and their gill slits are not covered They are found only in the sea. The bony fishes are the chief food fishes of the world.

QUESTIONS

1. How can you distinguish a fish from some other aquatic vertebrate ?
2. Why does a fish die when taken out of water?
3. Are there any fishes which can breathe air? Name one such Indian fish.
4. Do you know any fishes which bring forth their young alive?
5. What are the common food fishes of India?
6. Mention some uses of fishes other than for food.
7. Explain why a fish keeps on closing and opening its mouth
8. Some fishes produce millions of eggs each breeding season. Why is the ocean not choked with these fishes?

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CHAPTER 25

Amphibians—The Frogs and their Relatives

As the name amphibian indicates (Gk. *amphi*=both or double, *bios*=life), these animals have two phases in their life In the first or tadpole phase, they are fish-like creatures swimming in water. In the second or adult phase they also move about on land. Preston has nicely expressed it in the following poem

> 'And funny tadpoles that are fish,
> When in the stream they swim and swish,
> Take off their tails and climb a log,
> When it is time to be a frog'.

General Characters

The amphibians are cold-blooded vertebrates, most possessing two pairs of limbs with four toes in the fore-limb and five in the hind-limb. All except the toads have a moist skin rich in glands and lacking the protective hair, feathers or scales found in other vertebrates. Some legless amphibians have minute scales between the folds of the skin but these are rarely seen externally Some others, such as the toads, have a rough warty skin.

Distribution

Amphibians are confined generally to the moist temperate and tropical parts of the world and become scarce towards the cooler regions However, two species of frog and one of salamander inhabit the Arctic circle in Norway and Russia No amphibian is found in the sea. This appears to be due to the fact that the amphibian skin is highly permeable to water Amphibians generally obtain water through the skin, for which reason they must periodically return to water. But the sea water has a higher concentration of salts than in the amphibian body. This would result in the loss of water from the animal rather than its absorption.

Economic Importance

Frogs and toads feed on insects and thus keep down some of the pests which harm our crops. Frog's legs form a staple article of food in various parts of the world. Dried frogs and toads are sold in China for medicinal purposes Toad's skin has been used in Japan and elsewhere as a source of fine leather. In Japan dried salamanders are utilized as a vermifuge (a drug that expels worms from the intestine)

One of the most important uses of frogs and salamanders is their martyrdom to science. For a long time the frog has been a favourite object for the study of animal structure and function. Probably no other animal except man has been the subject of so many investigations Moreover, the frog is easily available. It is large enough to give a neat and clean dissection and is easy to handle. All aspects of the frog's life can be studied with thoroughness and convenience

Common Examples of Amphibia

Living amphibians can be divided into three groups: (a) the tailed amphibians, (b) the limbless amphibians, and (c) the tail-less amphibians.

The tailed amphibians, such as salamanders and newts (Fig. 25.1) are usually found in moist temperate regions They are mostly aquatic and breathe by means of gills throughout their lives. Unlike frogs they have long and slender bodies and the two pairs of limbs are nearly equal in size Some of the salamanders are brightly coloured, the upper parts olive green to brown and the underside pale. The largest salamander is over one metre long and is found in China and Japan.

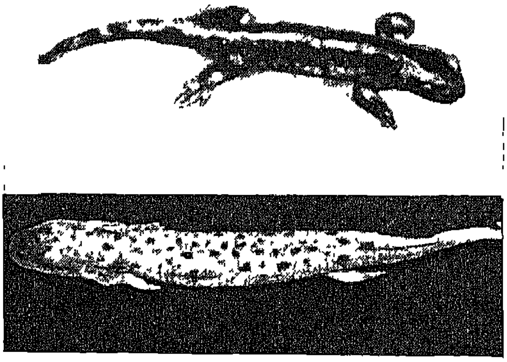


Fig. 25.1. The tailed amphibians — common salamander (top) and newt or mud puppy (bottom). The latter retains its feathery gills throughout life.

The limbless amphibians are found throughout the tropics but are seldom noticed owing to their burrowing habit. They resemble large earthworms. Their bodies are usually provided with a series of folds having small scales. Their eyes are hidden under the skin. *Ichthyophis* is a common Indian form whose female coils round her eggs to protect them (Fig. 25.2).

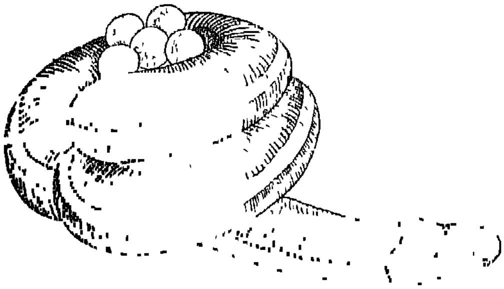
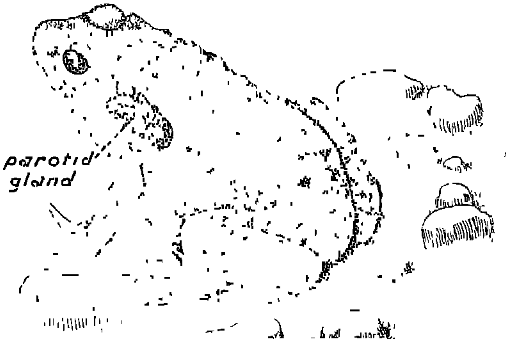


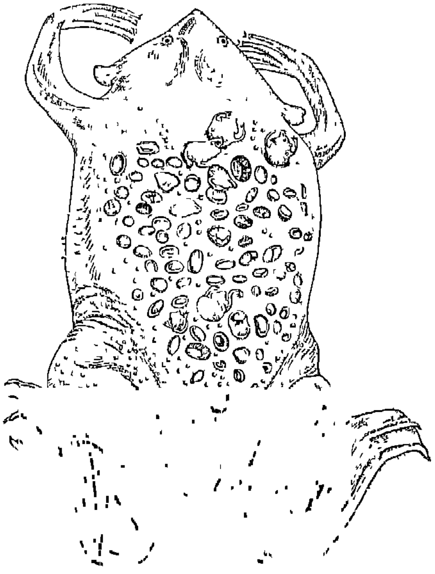
Fig. 25.2. *Ichthyophis glutinosa*, **a limbless amphibian.**

The tail-less amphibians comprise the frogs and toads. They are most abundant in the tropics. The adults have short, tail-less bodies with long hind-legs functioning as powerful levers in permitting them to make long leaps.

The common frog and toad are very similar animals, but what we generally see in our gardens are toads (Fig. 25.3). The differences between the two are not difficult to make out. The frog (Fig. 25.5) has a shapely body while the toad is flabby. The frog's skin is smooth and slimy but that of



COMMON TOAD



SURINAM TOAD

Fig. 25.3. Note the large parotid gland in the common toad, and young ones in the pits on the back of the Surinam toad.

the toad is dry, rough and covered with small swellings. These swellings are the poison glands in the skin. Just behind the eyes the poison glands are bunched together to form the oblong **parotid glands** which produce a thick milky secretion that is irritating and poisonous. If eaten by other animals, it may cause nausea, lowering of respiration and even muscular paralysis. Frogs and toads also show marked differences in the tongue, snout, teeth, toes and legs. These should be learnt from a study of the actual sepcimens.

About a dozen types of frogs are found in India. The Indian bull frog (*Rana tigrina*) is our commonest species. Other Indian frogs are the flying frog (*Rhacophorus maximus*) and the tree frog (*Hyla arborea*).

Our commonest toad is *Bufo melanostictus*. The midwife toad (*Alytes obstetricans*) of Europe and Surinam toad (*Pipa americana*) of Central America have interesting breeding habits. In the Surinam toad the female has numerous little pits provided with lids on her back (Fig. 25 3). During mating the male pushes the eggs from the female's protruding oviducts into the pits Each pit serves as a little pond for a developing egg. In the midwife toad the male carries the eggs around his hind-legs till the tadpoles are about to hatch (Fig. 25.4). These are unusual examples of parental care.

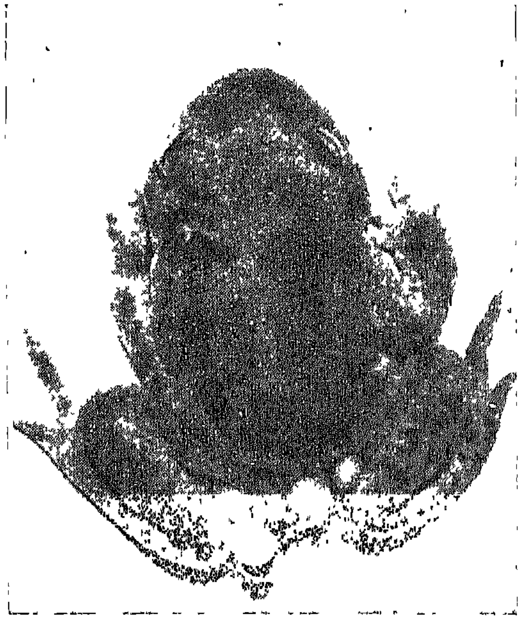


Fig. 25.4. The midwife toad; a string of eggs is wrapped round the hind-limbs of the male until they are ready to hatch.

FROG

We shall study the common Indian frog (*Rana tigrina*) in some detail to get an idea of the vertebrate body.

Habits and External Characters

Frogs live in or very close to ponds, lakes, canals and rivulets. This association with water has many advantages. They can readily jump into the water when chased by enemies on land The frog's skin is an important respiratory organ but it needs to be kept wet for proper functioning. Many kinds of insects, snails and earthworms, which constitute the common food of frogs, are also abundant near water. Moreover, water is absolutely necessary for the fertilization of frog's eggs and development of the larvae (*see* page 264)

In cold weather and in very dry periods frogs bury themselves underground in damp places. These periods of inactivity are termed 'winter sleep' and 'summer sleep' respectively. During these phases of their life they do not eat anything and live only on their stored fat. The body metabolism is reduced to a minimum and respiration through skin alone suffices. All the cold-blooded vertebrates undergo this period of suspended animation called **hibernation** (in winter) and **aestivation** (in summer).

Note the following features with the help of an animal kept under a bell-jar and compare with figure 25 5

1. The body is divisible into head, trunk and limbs. There is neither a neck nor a tail.

2. There are two main surfaces—dorsal and ventral.

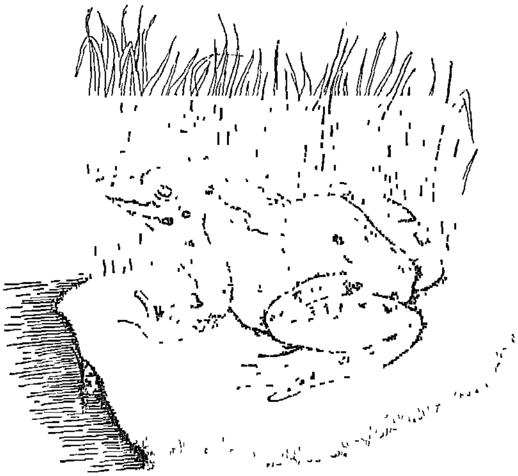


Fig. 25.5. The common Indian frog (*Rana tigrina*).

3 The head is flat and triangular with the blunt apex directed forwards The eyes are large and prominent. There are two eyelids of which the upper is thick, pigmented and almost immovable, while the lower is semi-transparent and freely movable. On gently touching the surface of the eye of a living frog you will note the raising of the lower eyelid and the inward movement of the whole eye A third eyelid, the **nictitating membrane,** is transparent. It covers and protects the eye during swimming Behind each eye is an obliquely placed dark circular patch, the eardrum or **tympanic membrane.**

4. There are two pairs of limbs The fore-limb consists of an upper arm, a forearm and a hand with four fingers. The thumb is very small and inconspicuous. The hind-limb is much longer and consists of a thigh, a shank, an ankle and a foot with five toes webbed together

5 Four external apertures or openings are seen on the surface. Note the wide mouth at the anterior end and the small circular cloacal aperture at the hind end

between the legs The nostrils are a pair of apertures on the dorsal surface of the head

In the male frog there is a pigmented thickening called the **copulation pad** on the inner edge of the first digit of the hands (Fig 25 6 B) It is markedly developed during the breeding season The male frog also carries a pair of loose folds of skin, called **vocal sacs,** on the ventral surface of the head. Frogs and toads are among the noisiest of animals, especially in their breeding season The croaking is done by closing the mouth and passing air to and fro between the lungs and mouth. The vocal sacs act as resonators to increase the sound and appear like little inflated balloons during croaking (Fig. 25.7)

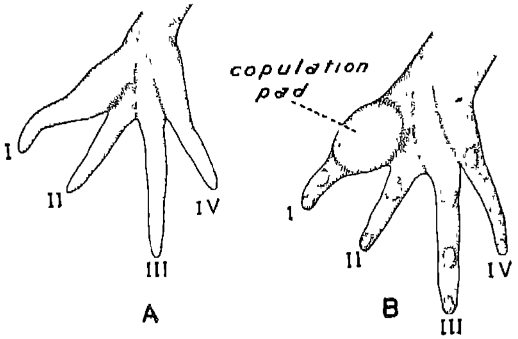


Fig.25.6. The hand of female (A) and male (B) frog. The copulation pad is seen only in the male.

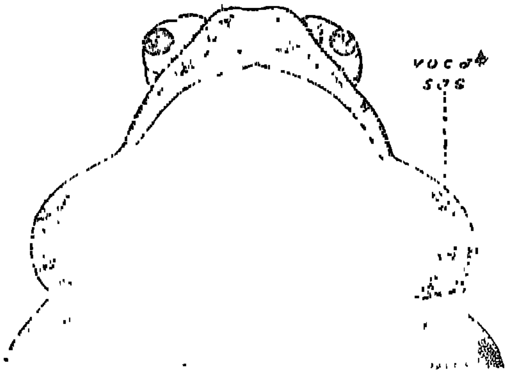


Fig. 25.7. The inflated vocal sacs of a male frog; with their help the frog produces the familiar croaking noise.

The study of the external features provides us an insight into the dual mode of a frog's life. The streamlined, boat-shaped body is a perfect adaptation to life in water This is further aided by the absence of projecting surfaces, the presence of a pointed snout which acts as a cut-water, and webbed feet which help in swimming The long hind-legs, though disproportionate, are helpful both in swimming and for leaping on land. The absence of a neck is compensated by the bulging eyes which enable the frog to scan its surroundings.

The skin on the back is mostly green with dark or brown patches The belly is pale-yellow. Frogs have the capacity to change colour. By matching this with the surroundings they are able to escape the notice of other animals. This type of protective colouration is termed **camouflage.** The change in colour is brought about by the dispersion or concentration of a pigment within the colour cells scattered in the skin The picture of the surroundings perceived by the eye causes a corresponding change of colour This is proved by the observation that blind frogs do not change colour adaptively.

Microscopic Structure of the Skin

A frog's skin is a 'jack of all trades' performing several functions. The first is that of protection because the skin wraps the entire body and safeguards the tissues against all mechanical injuries. It prevents the entry of germs. Its colouration helps the frog escape the notice of its enemies. It is also an important respiratory organ. To a certain extent the heat of the body is dissipated by evaporation from the surface of the skin. The frog does not drink water but maintains the necessary amount of moisture in the body by absorbing water through the skin.

There are two major layers of the skin : the outer **epidermis** and the inner **dermis** (Fig. 25.8). The epidermis is made up of several layers of cells. Time and again its outermost cells are shed and new cells take their place. These new cells are produced by the living (**malpighian**) layer of the epidermis. The skin is an efficient protective organ because it can stand wear and tear. The mucous glands open to the outside by means of small pores. The cells of the glands secrete a slimy fluid which keeps the skin moist and slippery. A large number of blood vessels are present in the dermis. The moist and highly vascular skin is, therefore, an efficient respiratory organ. The pigment-bearing cells are also contained in the dermis and they impart the characteristic green, golden, or dark colouration to the skin. The entire skin is loosely connected to the underlying muscles by strands of connective tissue

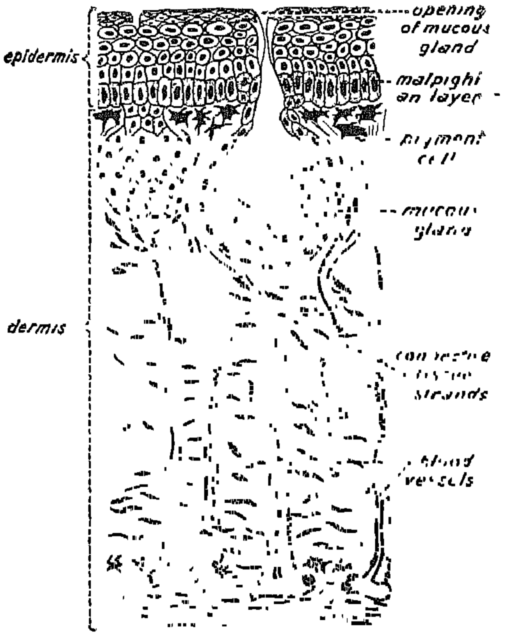


Fig. 25.8. Structure of skin as seen in the vertical section. The innermost layer of the epidermis (malpighian layer) undergoes active divisions and adds to the outer layers. The flask-shaped glands have small openings through which they pour out a sticky secretion. This makes the skin moist and slippery. After T J. Parker, W N. Parker, B L Bhatia and M.A. Moghe, *An Elementary Text-Book of Zoology for Indian Students*, Macmillan & Co., Ltd., London, 1957,

Skeleton

In all vertebrates the basic form of the body is maintained by bones and cartilage which constitute their skeletal system (Gk. *skeletos*=hard). Most bones are essentially supporting structures that keep the body from collapsing into a heap or lump. Figure 25.9 shows a profile of the frog's framework.

The skull is made up of a large number of bones that support the various organs of the head. The most prominent part is the central brain box or **cranium** which protects the delicate brain from injury. The upper jaw forms a half circle around the skull. The lower jaw supports the mouth and consists of two halves.

The backbone is made up of nine bones called vertebrae (singular—vertebra) and the last in the **vertebral column** is a long bony rod, the **urostyle.** Except the first, eighth and ninth vertebrae, all others are almost similar. A typical vertebra (Fig. 25.9) is a ring-like structure with lateral projections. On the roof of the ring is a small spine. The lower solid part or **centrum** is concave in front and convex behind, so that the bulge of the centrum of one vertebra fits into the front hollow of the next. Ligaments hold the vertebrae together, but allow certain movement. All the rings joined together form a long canal enclosing the spinal cord which is a backward continuation of the brain.

The shoulder or **pectoral girdle** supports the front part of the body at the level of the fore-limbs It is joined dorsally to the vertebral column by muscles and is connected on its ventral side with the breast bone.

The fore-limb (Fig. 25 9) has a thick cylindrical bone, the **humerus,** in the upper arm. Its rounded head fits into a cavity of the shoulder girdle. Its upper region has a prominent ridge while its lower end is almost rounded and fits into a cavity at the proximal end of the **radioulna** of the lower arm. The wrist consists of six small bones, the **carpals,** arranged in two rows The mid-hand consists of four long **metacarpals** to which the finger bones are attached, and a very small metacarpal (corresponding to the thumb) which is concealed by the skin.

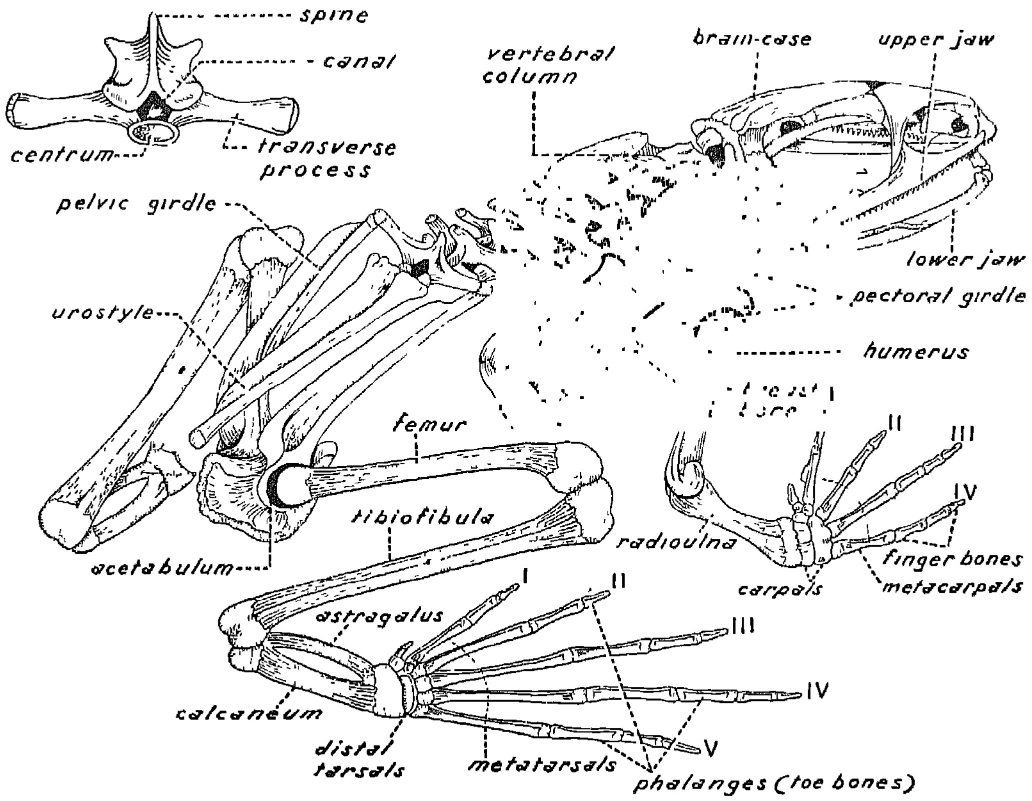


Fig. 25.9. Lateral view of the skeleton of a frog in sitting posture. The bones of the digits in the left hind-limb have been omitted. The anterior view of a typical vertebra is shown at top left. Courtesy of M.L. Bhatia, New Delhi.

The **hip** or **pelvic girdle** is modified to suit the hopping mode of locomotion. Anteriorly it is connected to the vertebral column by its two sword-like long bones.

The bones of the hind-limb (Fig 25.9) correspond in a general way with those of the fore-limb. The thigh has a single long **femur** whose upper rounded head articulates with a cavity of the hip girdle. Its lower end articulates with **tibiofibula** of the shank. The foot has three parts: the **tarsus, metatarsus** and **toes**. The tarsus has two long bones, **astragalus** and **calcaneum**, and two small bones in the distal row. The astragalus and calcaneum form an elongated ankle, an additional segment of legs helpful in jumping. There are five metatarsals to which the toe bones are attached.

Uses of skeleton. The skeleton forms the bony framework of the body and thus gives it a definite shape It protects delicate organs like the brain, spinal cord, heart and lungs. The muscles responsible for the movement of the body are attached to the bones. The bone marrow (*see* page 54) manufactures red blood cells

Nature of bone. In Chapter 6 you learnt that the bone is a kind of connective tissue with a heavy deposition of calcium salts 'But it is so unlike a tissue', you would perhaps say surprised It appears to be made entirely of lime or some sort of plaster. You can do a simple but instructive experiment to test the true nature of a bone. Just put a bone of frog, or of any other animal, in a beaker containing dilute hydrochloric acid An effervescence soon

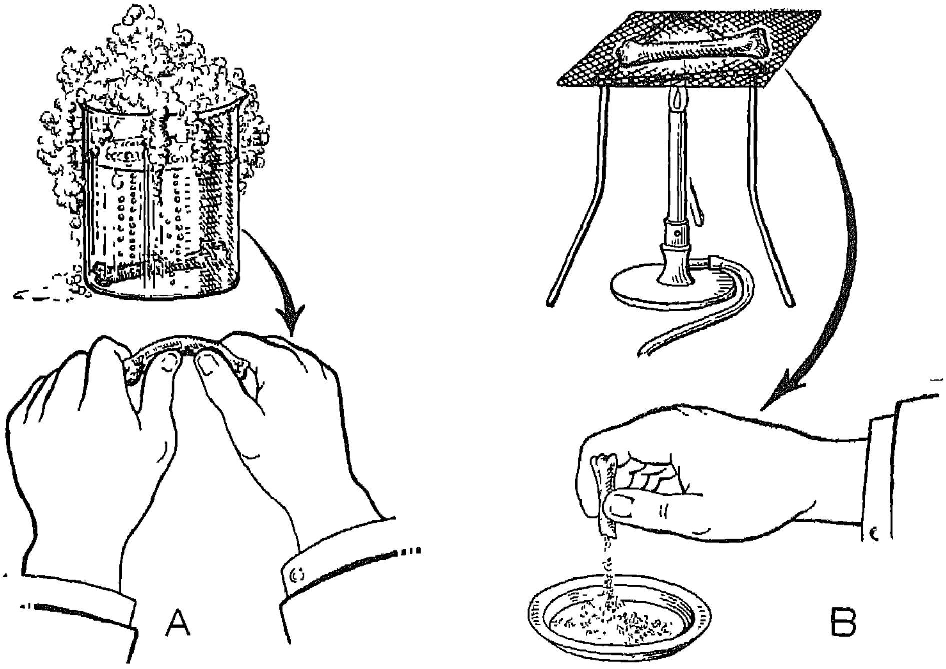


Fig. 25.10. The nature of the substance making the bones. Treatment with acid removes the rigid material (A) whereas burning removes the plastic material (B).

starts and perhaps you expect that the entire bone would dissolve like a lump of salt in water. But this does not happen Its shape remains unchanged though it becomes so soft that you can now bend it between your fingers (Fig. 25 10) If you release the pressure, it springs back to its original shape. The soft elastic material is mostly connective tissue On the contrary, if you were to put a bone in fire, the connective tissue would be burnt completely, leaving only the lime. It would now be so brittle as to crumble into powder.

Muscular System

The muscles are responsible for the movement of the various organs of the body. Most of them are attached to the bones at one or both ends. The attachment may be direct or through a tendon (a band of tough, inelastic connective tissue).

Muscles are usually arranged in antagonistic pairs (flexors and extensors) which effect opposite movements. **Flexors** bend a joint while **extensors** straighten it. The muscles of the urinary bladder, intestine, heart and other internal organs are not under the organism's voluntary control and are therefore known as involuntary. On the other hand, the muscles of the legs and arms (and all other skeletal muscles) can be worked at will and are called voluntary.

The Coelome and Viscera

On cutting open the main body or trunk of the frog, a large body space containing the various internal organs is exposed (Fig. 25.11). This cavity is the coelome and the contained organs are the **viscera.** The entire body space is lined with a thin glistening membrane, the **peritoneum.** Towards the dorsal side, this membrane is reflected back over the visceral organs, and forms the suspensory structures. The smooth peritoneal covering over the visceral organs protects them from mutual friction. A fluid contained in the coelome also lubricates the viscera. The various organs seen here are described under respective systems.

Digestive System

The food passage or the **alimentary canal** begins at the mouth and is continued up to the cloacal aperture as a long convo-

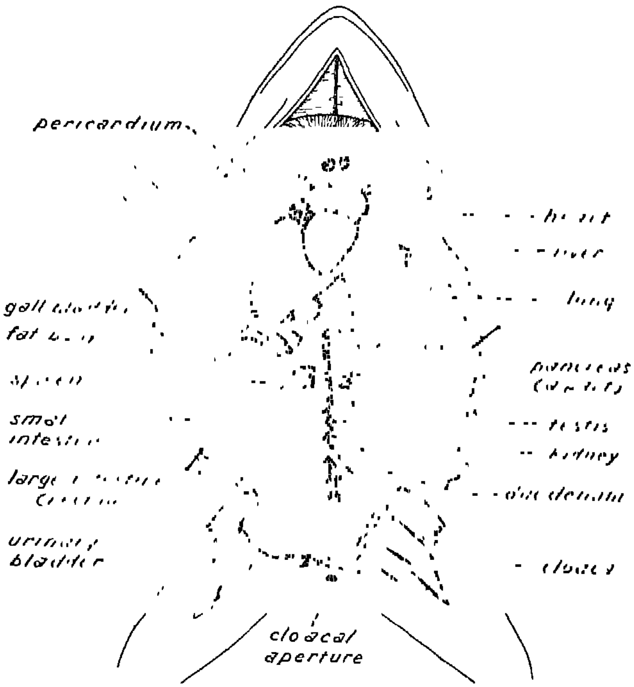


Fig. 25.11. **Disposition of the alimentary canal and other internal organs of a frog cut open from the ventral side.**

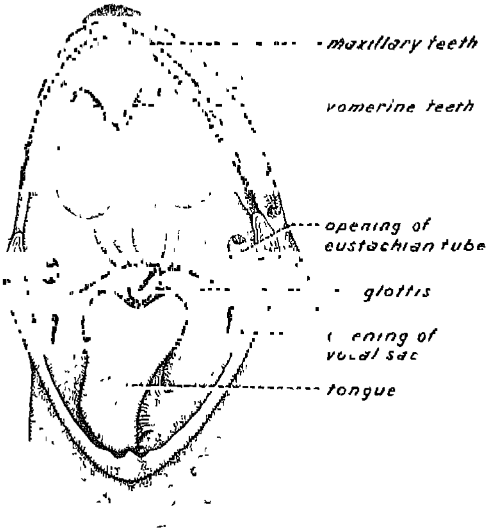


Fig. 25.12. **The two jaws of a frog have been stretched wide open to show the buccal cavity.**

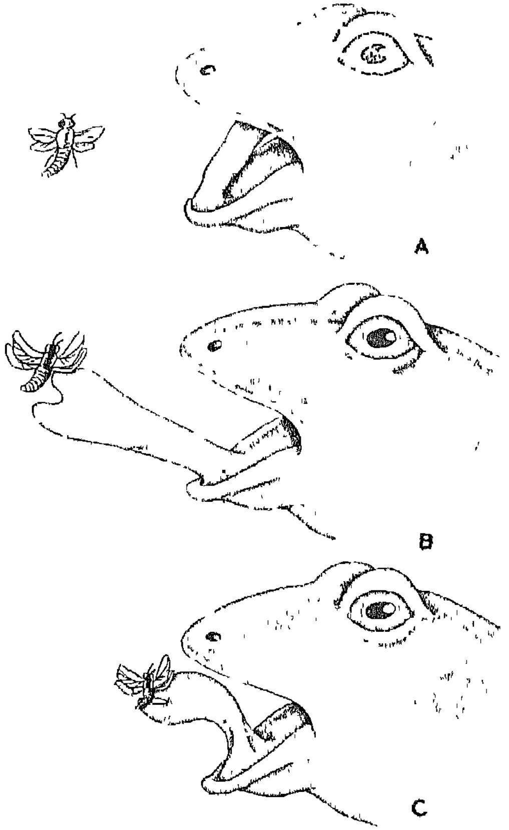


Fig. 25.13. **The frog's tongue is free at the back but attached in front. At the time of catching a prey the tongue is rapidly thrust out (A). The prey sticks to the slimy tongue (B) which is then withdrawn immediately (C).**

luted tube. Several distinct regions can be made out. These are the throat (pharynx), oesophagus, stomach, small intestine, large intestine and cloaca. Two other organs—**liver** and **pancreas**—are also associated with the food canal (Fig. 25.11).

The **buccal cavity** or mouth cavity (Fig. 25.12) contains a large, muscular, sticky tongue. It is attached at the front end while its back end is free and forked. To catch the prey, the tongue is rapidly shot out. The prey sticks to its slimy surface and is drawn in with lightning speed (Fig. 25 13). The **maxillary teeth** of the upper jaw and the **vomerine teeth** on the roof of the buccal cavity prevent the prey from slipping out. The buccal cavity narrows behind to form the **pharynx**. There are no digestive glands in the mouth, and therefore, the food does not undergo any change here. The prey is not chewed, but is gradually swallowed through the pharynx into the short, tubular **oesophagus.** The movement or backward pushing of the food is caused by a wave of contraction (**peristalsis**) of involuntary muscles in the wall of the oesophagus. The food now reaches the stomach.

The **stomach** is not sharply marked off from the oesophagus. Its large anterior part is broad while the posterior part is narrow. The wall of the stomach is highly muscular and folded, and allows its distension when the food is received. It has numerous gastric glands whose secretion (**gastric juice**) is poured into the cavity of the stomach. The stomach also produces a slimy fluid that lubricates its wall and the food. A narrow valve (**pyloric valve**) at the posterior end of the stomach opens to allow the partially digested food to pass into the **duodenum** (anterior part of the small intestine). A narrow tube, called the **common bile duct**, brings into it some juices from the liver and the pancreas (Fig. 25 14). The liver is a large, reddish, three-lobed organ located close to the heart and lungs. It is made up of innumerable polygonal cells. Their secretion or the **bile** flows through fine channels or the bile passages in between the cells The bile passages unite to form larger tubes which open into a thin-walled greenish sac, the **gall bladder.** The bile is stored here for sometime and later passed into the bile duct. The bile duct runs through the pancreas located in the U-shaped region between the stomach and duodenum. The **pancreas** is a much branched yellowish organ, formed of glandular cells. During its course through the pancreas, the bile duct is joined by the

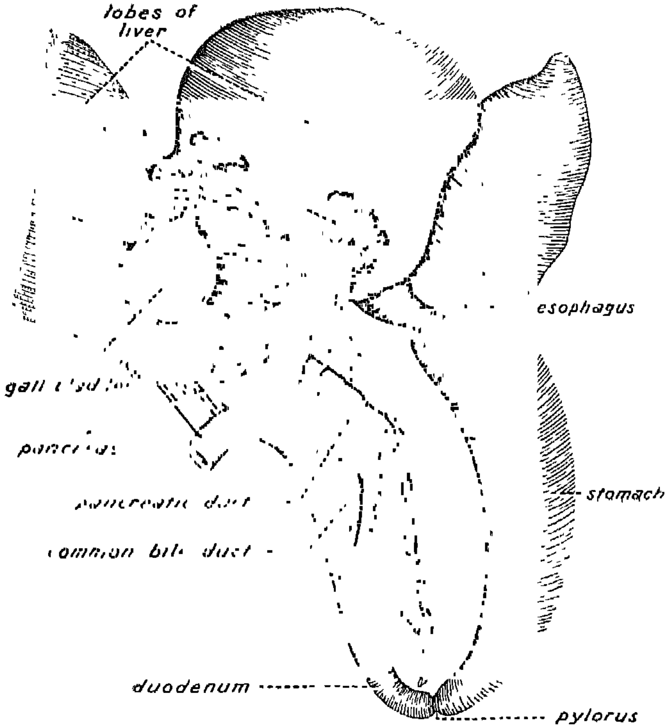


Fig. 25.14. The liver, gall bladder, pancreas and the adjoining parts of the alimentary canal. After T J. Parker, W.N. Parker, B.L. Bhatia and M A. Moghe, *An Elementary Text-Book of Zoology for Indian Students*, Macmillan & Co., Ltd., London, 1957.

pancreatic ducts. The alkaline **pancreatic juice** contains digestive enzymes. The bile contains no enzymes but its bile salts break fats into a soapy solution (emulsion) of small droplets which make them easier to digest.

The partially digested food now reaches the **ileum** (posterior part of the small intestine) where the intestinal glands contained in its wall pour their enzymatic juices over it. The food is broken down into simpler substances and is absorbed in the wall of the intestine. The indigestible material continues to move posteriorly by peristalsis similar to that in the oesophagus. Finally it accumulates in the **large intestine** or **rectum.** From here it passes into the sac-like **cloaca** which empties the waste matter or faeces to the outside through the **cloacal aperture.** The digested food is picked up by the blood vessels of the intestinal walls and is carried to the various parts of the body The nutrients in excess of the needs of the body are stored up in the liver

Respiratory System

Organs of the body which help in the intake and absorption of oxygen constitute the respiratory system These organs are the lungs and skin in the adult frog, and the gills in the tadpole. When free air or air dissolved in water comes in contact with these organs, the blood flowing through them picks up oxygen and gives out carbon dioxide. The blood then distributes oxygen to every part of the body and collects carbon dioxide.

The adult frog respires through the skin, (**cutaneous respiration**), through the lining of the mouth cavity (**buccal respiration**), and through the lungs (**pulmonary respiration**).

Cutaneous respiration is the only mode of respiration when the animal is under water or is hibernating. Even while on land, it respires partly by means of its skin and partly by the lungs. The skin is richly supplied with blood vessels. Its moist surface serves for the diffusion of gases.

The frog always keeps its mouth closed, except while catching its prey. If you observe a living frog sitting on land or floating in an aquarium, you will find it

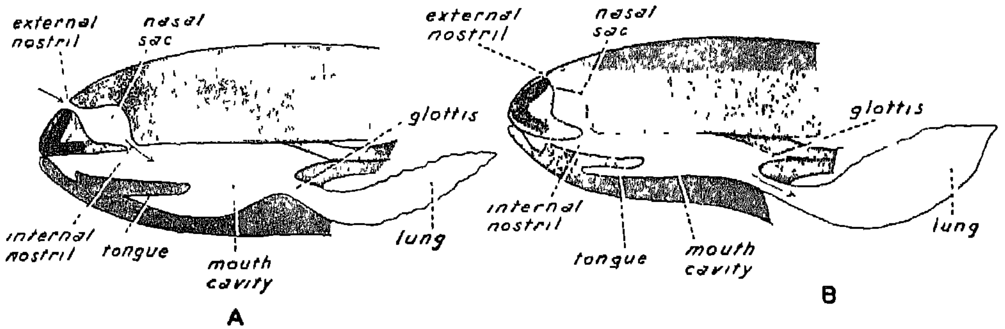


Fig. 25.15. The mechanism of pulmonary respiration in frog. As the floor of the mouth is lowered, the nostrils open and air is drawn into the mouth cavity (A). When the floor is raised, the nostrils close and air is pushed into the lungs (B). After T.J. Parker, W.N Parker, B L. Bhatia and M A Moghe, *An Elementary Text-Book of Zoology for Indian Students*, Macmillan & Co., Ltd., London, 1957.

constantly raising and lowering the floor of its buccal cavity. When it lowers the floor, the air is drawn in through the external and internal nostrils and brought into the mouth cavity. The air is forced out through the same route when the floor is raised. During these movements the slit-like **glottis** or the opening from the throat to the lungs remains closed and the air does not enter the lungs. The entire lining of the mouth cavity has a rich supply of blood capillaries The oxygen in the air is absorbed by the blood while carbon dioxide is given out.

In pulmonary respiration (Fig. 25 15) air is forced from the mouth cavity into the lungs through the glottis This intake is called **inspiration** while the forcing out of the air from the lungs is termed **expiration.** The lungs are ovoid, elastic sacs, somewhat reddish in freshly dissected specimens. At the front the two lungs open into a small, thin-walled **laryngo-tracheal chamber** which opens into the pharynx through glottis (Fig. 25.16). The walls of the chamber and the edges of the glottis are strengthened by cartilages. The laryngo-tracheal chamber forms the voice box. Its internal lining is raised into a pair of horizontal folds called vocal cords. When the air is forced out of the lungs the cords begin to vibrate Muscles change the tension of the cords and the pitch of the sound can be varied The vocal sacs, found only in the male frog, amplify the croaking sound.

Internally, each lung is divided by numerous folds into compartments called **alveoli** or air spaces. These considerably increase the surface exposed to the air. The entire lining of the lungs is richly provided with blood capillaries. The interchange of gases takes place in the air spaces of the lungs. The blood brought to the lungs is laden with carbon dioxide which is got rid of, and oxygen is absorbed from the inhaled air. The oxygenated blood then flows through the veins of the lungs and reaches the heart from where it is pumped to different parts of the body.

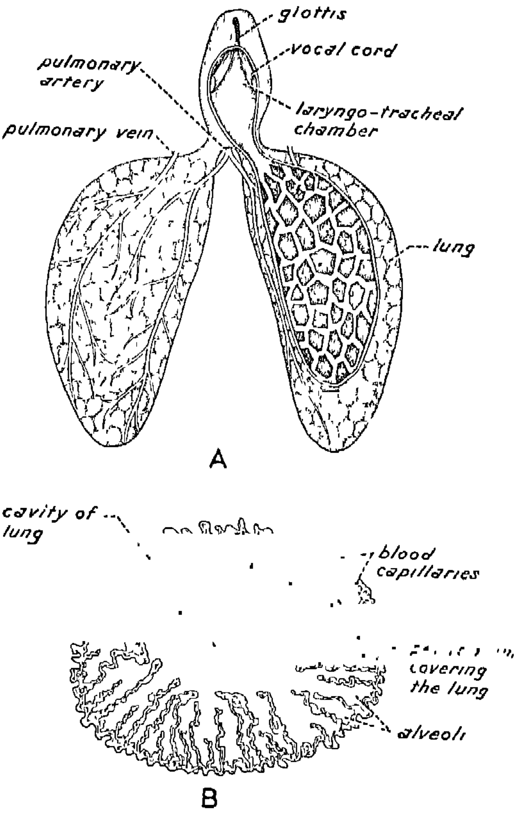


Fig. 25.16. **A. Respiratory organs of frog seen from the ventral side. A portion of the laryngo-tracheal chamber has been cut open. B. Transverse section through the lung.**

In lung respiration the mouth cavity acts as a force pump. The movements of the floor of the mouth cavity are the same as in buccal respiration but this time the glottis opens and air is forced into the lungs. During expiration the elasticity of the lungs, aided by the contractions of the body muscles, forces the air out of the lungs into the buccal cavity. Then this air may be expelled through the nostrils.

Circulatory System

The frog's body contains two chief fluids, the **blood** and the **lymph**. Both blood and lymph circulate in the body and serve to distribute the absorbed food material and oxygen. They also collect the waste substances produced in the body and bring them to the organs of elimination. The blood flows in tubular channels called blood vessels, and its flow is maintained by a strong muscular pump, the heart. The lymph is colourless and flows through lymph capillaries, lymph vessels, lymph 'hearts' and lymph spaces situated most commonly under the skin and beneath the backbone.

The blood is made of a liquid part, the **plasma**, and a cellular part, the **corpuscles**, floating in it. The plasma is an almost colourless fluid, but it has a variety of substances dissolved in it. The commonest of them are carbon dioxide, digested foodstuffs (amino acids, glucose, fat droplets, etc.), many salts, waste products (like urea), vitamins, hormones, and protective substances like antitoxins. The plasma also contains a substance called **fibrinogen** which is responsible for the clotting of blood. Normally, fibrinogen is in a dissolved state but whenever the blood is exposed to the air, as in a wound, or when it comes in contact with some foreign material, the fibrinogen precipitates into delicate threads called **fibrin.** The remaining plasma is now a clear liquid called the **serum.** The fibrin and the corpuscles entangled in it form the **clot** from which the serum flows out. The clot prevents the escape of more blood at the site of the cut. Platelets or thrombocytes also help in clotting.

The blood corpuscles (Fig. 25.17) are of three kinds: red corpuscles (**erythrocytes**), white corpuscles (**leucocytes**) and platelets (**thrombocytes**). The red corpuscles are biconvex, elliptical discs in which the central part contains the nucleus. In one cubic millimetre of blood there are more than half a million of the red blood corpuscles. Their cytoplasm is almost transparent and contains an iron-protein compound known as haemoglobin. This substance has a strong affinity for oxygen. The red corpuscles are not really red. Individually they are yellowish, but in a mass they appear red.

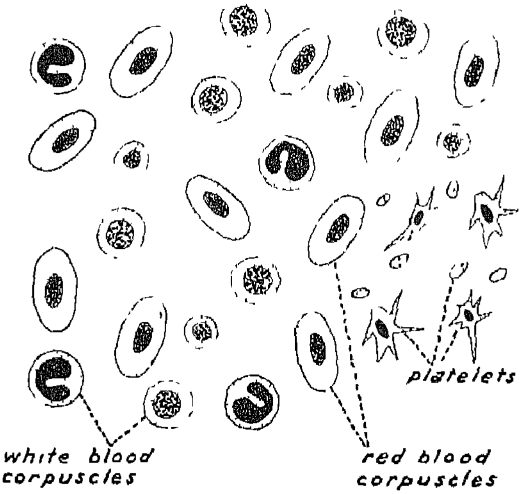


Fig. 25.17. The three kinds of corpuscles in the blood of frog.

The white blood corpuscles do not have a definite size or shape. They have a semi-transparent, colourless cytoplasm. Often they show irregular outgrowths (somewhat like those of an amoeba). The nucleus may be lobed or even divided. Owing to their amoeboid movements, the white corpuscles can even pass through the walls of the blood capillaries into the intercellular spaces of the tissues. The platelets or thrombocytes are spindle-shaped bodies (Fig. 25 17) capable of amoeboid movements only in the young stage.

The corpuscles die after functioning for a certain time. They are then picked up from the circulating blood and destroyed chiefly in the **spleen** which is a dark red, oval organ lying close to the coils of the intestine. New corpuscles are formed in the bone marrow and the spleen. This regeneration is most active in the warm season. The spleen has numerous small spaces which store the blood corpuscles for use in an emergency.

Through the capillary walls the plasma (except some proteins) oozes out into the intercellular spaces. This fluid is called the **lymph** or tissue fluid. The living cells are bathed in this nutrient- and oxygen-rich fluid and the wastes are given off into it A part of the lymph diffuses back into the capillaries and partly it moves slowly through intercellular spaces until it reaches the lymph vessels, some of which pulsate slowly to propel the fluid. These are the 'lymph hearts'.

Circulation of blood in the body. The circulatory system consists of a heart that works as a pump, arteries that carry blood to the different organs, capillaries and veins which bring the blood back to the heart. The blood capillaries (Fig. 25 18) are extremely thin-walled vessels which arise from the ultimate distributing branches of the arteries and connect them with the collecting veins. Unlike lymph, blood does not flow freely around the body cells; it is always contained in the tubular passages.

The arteries have thick muscular walls and a relatively narrow inner passage while the veins have thin, non-elastic walls and a broader passage (Fig 25 19 A). The arterial blood is under considerable pressure and flows with jerks which can be detected as 'pulse' each time the heart beats The venous blood, on the other hand, is under low pressure and flows slowly and evenly.

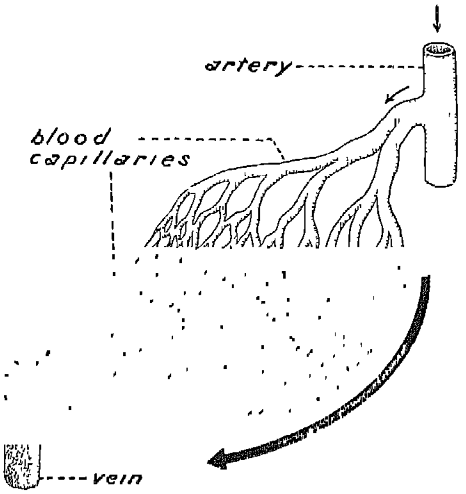


Fig. 25.18. The blood capillaries form a fine network connecting an artery with a vein.

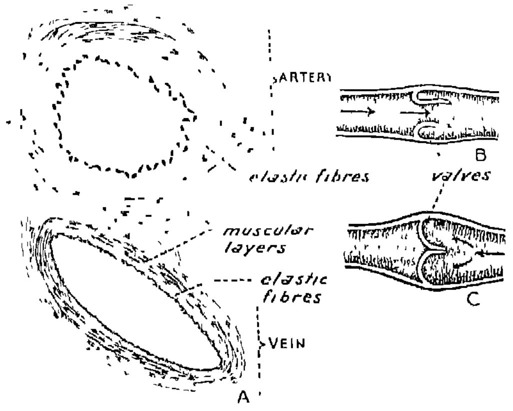


Fig. 25.19. A. Transverse section of an artery and a vein; note the thicker muscular walls in an artery. B and C. Longitudinal sections of veins to show the action of valves.

The veins have pocket-shaped valves (much like those in the lymph vessels) which prevent the blood from flowing in the reverse direction (Fig 25 19 B and C) The arteries are more deeply placed in the body than are the veins

The heart is somewhat conical and lies ventrally at the level of the shoulders just above the breast bone. It is enclosed by a thin, double-walled sac, the **pericardium** Between the two layers of the pericardium lies the pericardial fluid (a part of the lymph), which protects the heart from any friction or mechanical shocks

The heart has three chambers. Of these the upper two are smaller, thin-walled, and are called the right and left **auricles** The lower conical chamber, which is larger than the upper two, is known as **ventricle** (Fig. 25.20)

The internal structure of the heart can be understood from figure 25 21 The thin-walled auricles are separated from each other by a partition. They open into the ventricle by a common aperture which is protected by a valve consisting of two flaps These flaps remain projecting into the ventricular space and are held in position by several cords arising from the ventricular walls.

Blood from the body flows into a collecting chamber, the **sinus venosus,** and from there it enters the right auricle The opening between the sinus venosus and the right auricle is also guarded by valves. Similarly, blood from the lungs enters the left auricle through the two **pulmonary veins**. There is no valve at this opening. The ventricle has very thick muscular but spongy walls. From the right side of its broader end arises

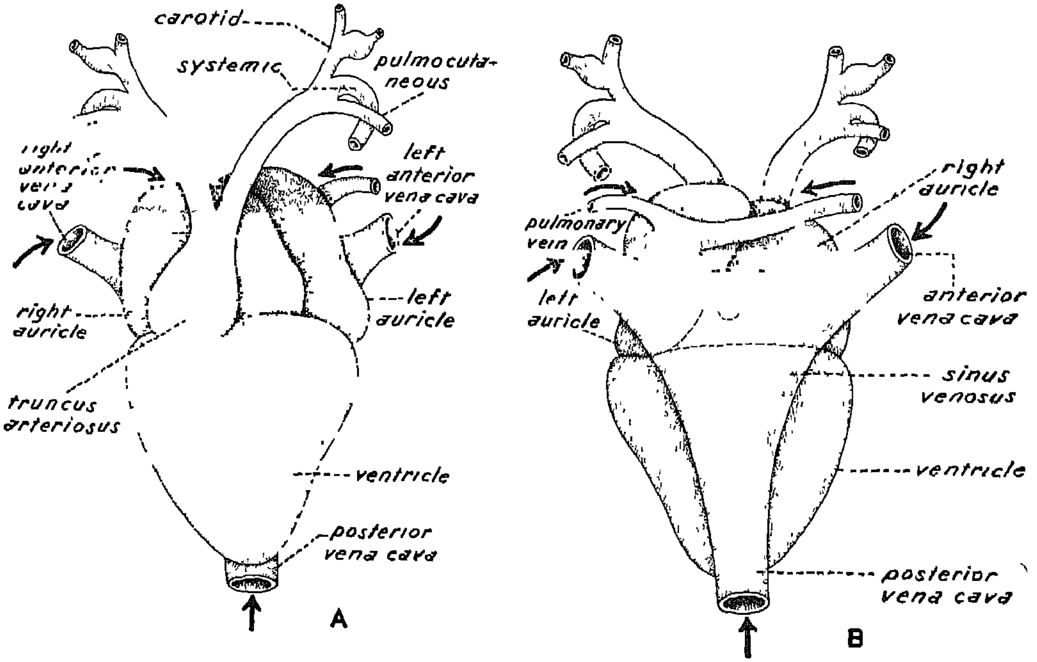


Fig. 25.20. The heart in dorsal (A) and ventral (B) views. After T J Moon, J H. Otto and A. Towle, *Modern Biology,* Holt, Rinehart and Winston, Inc., New York, 1960.

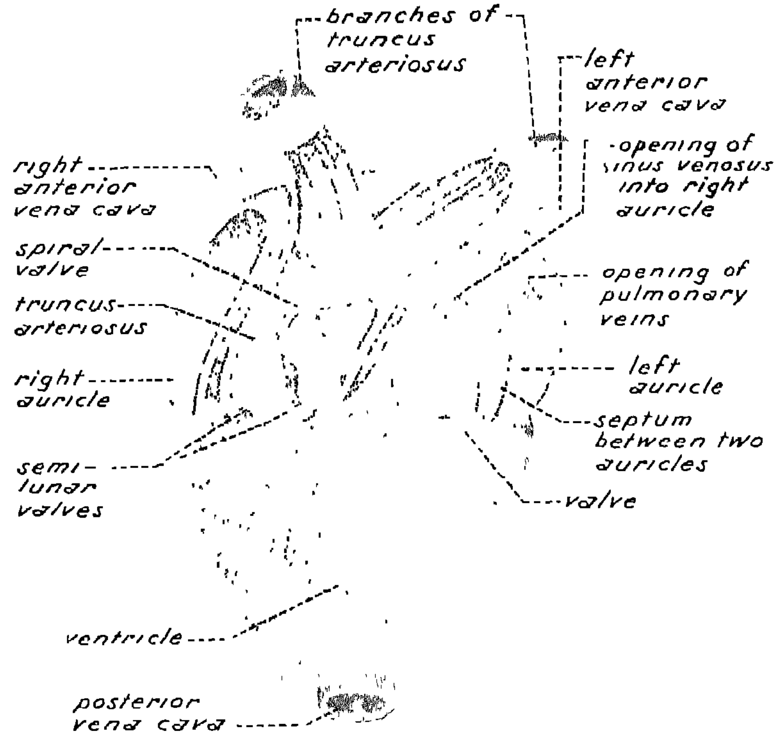


Fig. 25.21. Longitudinal section of the heart. After E T. Smith, *Exploring Biology*, Harcourt, Brace & World, Inc, New York, 1959

a large artery (**truncus arteriosus**) which runs over the surface between the two auricles Further up it divides into three pairs of arterial trunks (**carotid, systemic** and **pulmocutaneous**), those of each side forming a sort of bundle for a short distance Three semi-lunar valves (Fig. 25.21) at the base of the truncus arteriosus prevent the return of the blood into the ventricle A longitudinal spiral valve within the truncus arteriosus directs the flow of blood first into the pulmocutaneous (lung-skin) trunk and later into the systemic (body) and carotid (head) trunks. At the bases of all the three pairs of arterial trunks there are valves to regulate the flow of blood only in one direction.

Mechanism of the heart. The heart beats rhythmically by its muscular walls. Each beat results from a contraction and a relaxation. The contraction of the different chambers takes place in a definite sequence —first the sinus venosus, then the auricles, the ventricle, and finally the truncus arteriosus. With the contraction of the sinus venosus the blood is forced into the right auricle. Meanwhile, the oxygenated blood from the lungs is poured into the left auricle. Then the two auricles contract simultaneously. The valves at the opening between the sinus venosus and the right auricle prevent the return of blood into the sinus In the left auricle the steady flow of blood from the lungs itself prevents its return into the pulmonary veins As a result of the contraction of the auricles, the blood is forced into the ventricle through the single auriculo-ventricular aperture. The blood in the extreme right of the ventricle is deoxygenated while that on the extreme left is oxygenated. In its middle region there is some mixing of the two types of blood, but owing to the viscous nature of the blood the two kinds mix very slowly.

The ventricle contracts immediately after the contraction of the auricles. The pressure of the contained blood closes the auriculo-ventricular valves and the blood is thus stopped from returning to the auricles. On the other hand, the pressure forces open the valves at the base of the truncus arteriosus. First the largely deoxygenated blood from the right side enters the truncus and reaches the pulmocutaneous trunk Next, the mixed blood flows into the systemic trunk, and finally the largely oxygenated blood enters the carotid trunk leading to the head region. Some biologists believe there is a complete mixing of blood in the ventricle and only the mixed blood flows throughout the body. Certainly there is some mixing. Thus, the amphibian heart is not as efficient as the four-chambered heart of some reptiles, birds and mammals in which there is a complete separation of the arterial and the venous blood

The heart pulsates continuously and keeps pumping blood to different organs of the body. The veins bring the blood back to the heart. This process goes on undisturbed throughout life. The same direction of flow is maintained on account of the valves at all important 'gateways' or openings of the chambers of the heart, and in the veins. The main arterial trunks divide into various branches as shown in figure 25.22. The principal veins are also shown in the same figure.

Portal systems. While the blood from most parts of the body reaches the heart directly, that from the legs and pelvic region passes through the kidneys, and that from the digestive tract through the liver. The blood vessels going through the kidneys form the **renal portal system** while those passing through the liver form the **hepatic portal system.**

The foregoing account would have shown you that the blood circulates through every part of the body. The capillary system is so profuse that you can hardly prick any portion of the body without injuring several of them During its journey through the tissues the blood renders a valuable service It transports oxygen and food materials to the cells and removes carbon dioxide and other waste matter from them. These are filtered out in the lungs and kidneys. The blood also carries secretions from certain glands situated in different parts of the body, and delivers them at the proper places. We shall elaborate on these statements later in Section IV.

Endocrine Glands

There are certain glands in the body of frog which produce substances (hormones or internal secretions) that are directly poured into the blood passing through them. These substances regulate metabolism, growth and reproduction. The glands themselves are called the **endocrine** or **ductless glands** (Fig. 25.23). The chief of them are the pituitary, thyroid, thymus, adrenals, pancreas and the gonads (testes or ovaries).

The **pituitary gland** is situated on the ventral side of the brain. It consists of three lobes. The anterior lobe secretes a growth-stimulating hormone and a gonad-stimulating hormone. If the anterior lobe from a breeding female frog is transplanted into a non-breeding female, her ovaries become activated and eggs are laid. Similarly

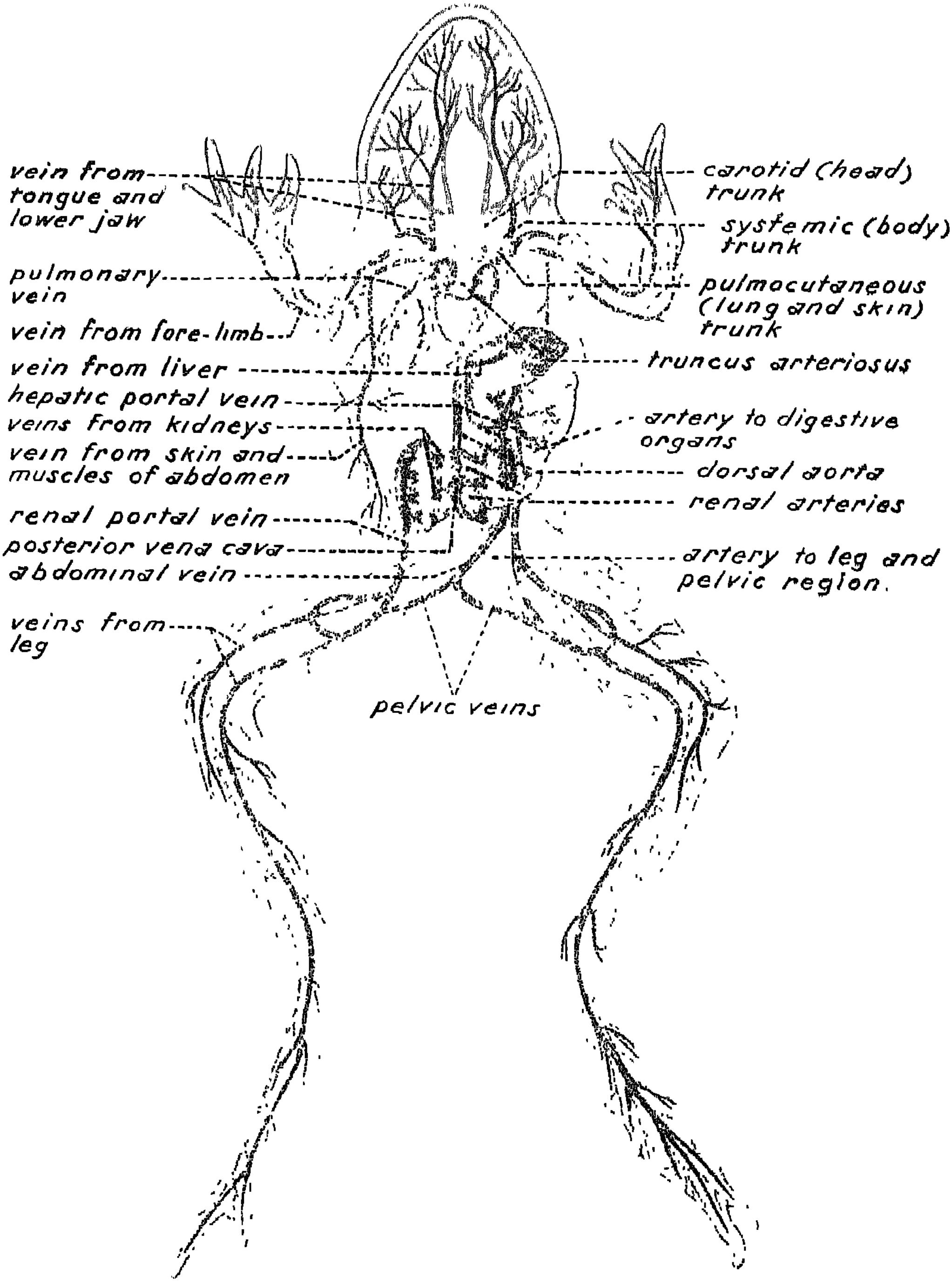


Fig. 25.22. The principal arteries and veins. After E.T Smith, *Exploring Biology*, Harcourt, Brace & World, Inc., New York, 1959.

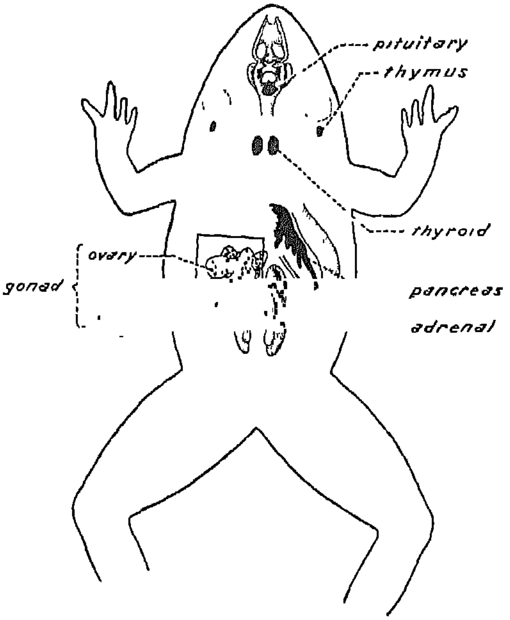


Fig. 25.23. The endocrine glands.

the corresponding lobe from a breeding male implanted in a non-breeding male results in the production and discharge of sperms. The hormone from the middle lobe regulates the distribution of pigment in the skin. The posterior lobe secretes a hormone that controls the intake of water by the skin.

On either side of the posterior part of the tongue is located a **thyroid gland.** Its secretion is responsible for the metamorphosis of a tadpole into an adult. If this gland is removed from the tadpoles they never turn into adults. On the other hand, in normal tadpoles its addition hastens their metamorphosis.

The **thymus** is a small, oval, somewhat reddish gland situated behind the tympanic membrane. It diminishes in size with age. Its function is not well understood. Biologists have ascribed to it several functions like control of the production of red blood cells, stimulation of the development of gonads and the control of metamorphosis.

The **adrenals** are yellow, streak-like bodies, situated one on the ventral surface of each kidney They produce adrenalin which increases the blood pressure and contracts the pigment cells of the skin.

The pancreas produces certain digestive enzymes and a hormone **insulin.** The insulin is secreted by special groups of cells called the **Islets of Langerhans** which are not so evident in frog, but are quite prominent in man, rabbit, etc. Insulin regulates the sugar balance in the body.

The **gonads** (testes or ovaries) produce hormones which stimulate the development of secondary sexual characters (such as the copulatory pad of the male).

Besides the above endocrine glands even the epithelial linings of the stomach and intestine act in a similar manner and their secretions regulate the flow of juices into the duodenum You will learn more about the hormones in Section IV.

Nervous System

The frog, as any other living being, performs two kinds of actions (*a*) voluntary actions which originate by its will, such as the reactions involved in catching a prey, and (*b*) involuntary or reflex actions which arise without thinking, such as the withdrawal of the foot on receiving a prick of needle. In both types of reactions the animal tries to adjust to its environment. This implies the perception of stimuli from the outside world and direction of the body muscles to perform the required actions. These functions are directed by the nervous system.

The nervous system consists of three parts . (*a*) **central nervous system,** which includes the brain and the spinal cord; (*b*) **peripheral nervous system** consisting of the nerves given off from the brain and the spinal cord; and (*c*) the **sympathetic nervous system.**

Brain. The brain is fully protected by the bony brain box of the skull. Its posterior continuation or the **spinal cord** is similarly concealed in the canal of the vertebral column. Both brain as well as spinal cord are covered over by two membranes. The outer is rather stiff while the inner is thin and contains blood capillaries. Between these two layers occurs a fluid which further protects these delicate parts from shocks.

The brain has three main divisions—fore-brain, mid-brain, and hind-brain (Fig. 25.24). The fore-brain includes **olfactory lobes** at the anterior end, two elongated cerebral lobes together called the **cerebrum** and a small **diencephalon** behind the cerebrum. On the dorsal side of the diencephalon occurs a small stalk-like **pineal body** of unknown function, and ventrally there is another lobe carrying the pituitary body. The mid-brain consists of two large optic lobes. The hind-brain has a small **cerebellum** and a large **medulla oblongata** which continues back into the spinal cord. The brain receives messages from the special

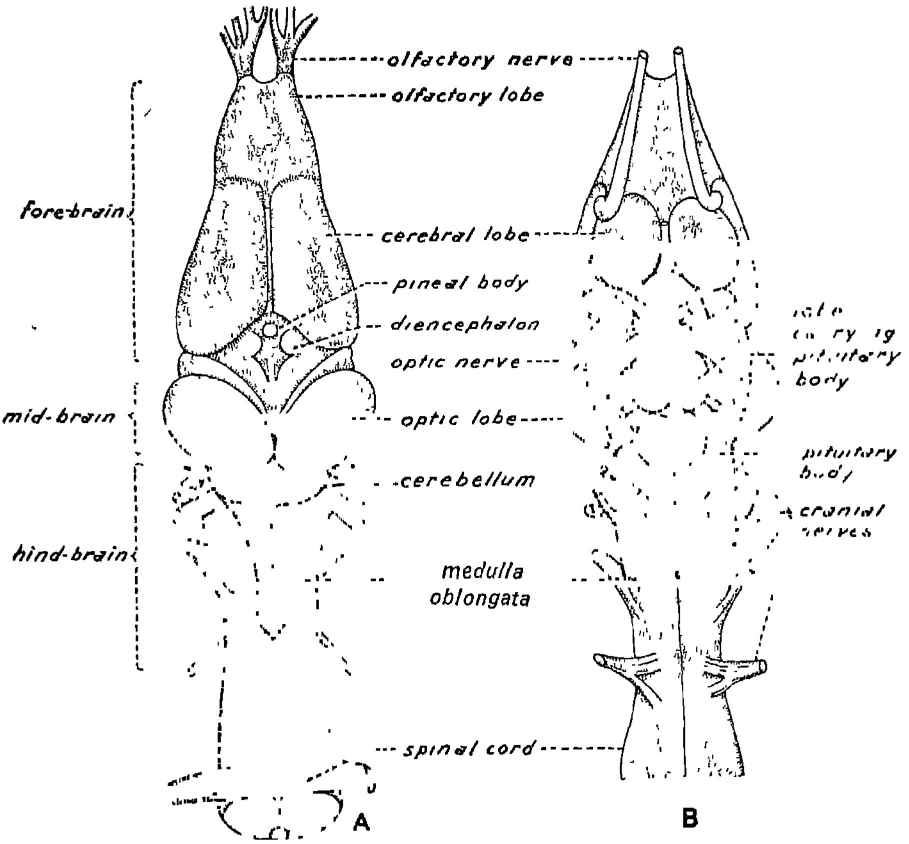


Fig. 25.24. Dorsal (A) and ventral (B) aspects of the brain. After T J. Parker, W.N. Parker, B L Bhatia and M A Moghe, *An Elementary Text-Book of Zoology for Indian Students*, Macmillan & Co., Ltd., London, 1957.

sense organs and directs the muscles to act according to the need. It is mainly concerned with voluntary actions. The cerebrum is the seat of learning and thinking, and it controls the general co-ordination of the functions of the other parts of the nervous system. The olfactory lobes are the seat of the sense of smell. The cerebellum co-ordinates the muscular movements, such as during jumping and swimming. The medulla oblongata regulates the movements of the heart and some other involuntary activities.

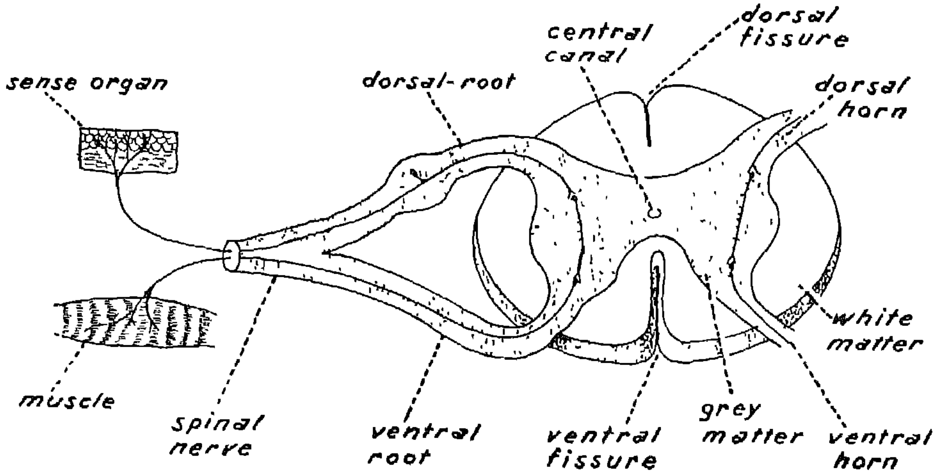


Fig. 25.25. **Cross section of the spinal cord, and the path of a reflex arc.**

Spinal cord. The spinal cord extends from the medulla oblongata to the end of the vertebral column. It has mid-dorsal and mid-ventral fissures (grooves) which look like streaks from the outside. A microscopic study of its cross section reveals the general structure as shown in figure 25.25. Centrally there is a canal which continues throughout the length and expands into the brain. Surrounding the central canal is the grey matter (containing nerve cells) and external to it is the white matter (containing nerve fibres). The grey matter is continued upwards and downwards as dorsal and ventral horns.

The spinal cord conducts the nerve impulses to and from the brain with the help of numerous interconnecting longitudinal and transverse nerve cells. Besides, it also conducts reflex nerve impulses that do not travel to and from the brain.

In **reflex action** the sensory impulse from an organ reaches the spinal cord through the dorsal (sensory) root of the spinal nerve. It is converted there into an 'order' which is immediately sent back through the ventral (motor) root to the concerned muscle for the necessary movement (Fig 25.25). Such action is less time-consuming because the stimulus need not travel all the way to the brain. If you take a decapitated frog (that is, a frog with the head removed) and put a drop of weak acid on its body, it is still able to react to this stimulus (Fig. 25.26). Such a frog may even use the other leg for wiping off the irritating substance.

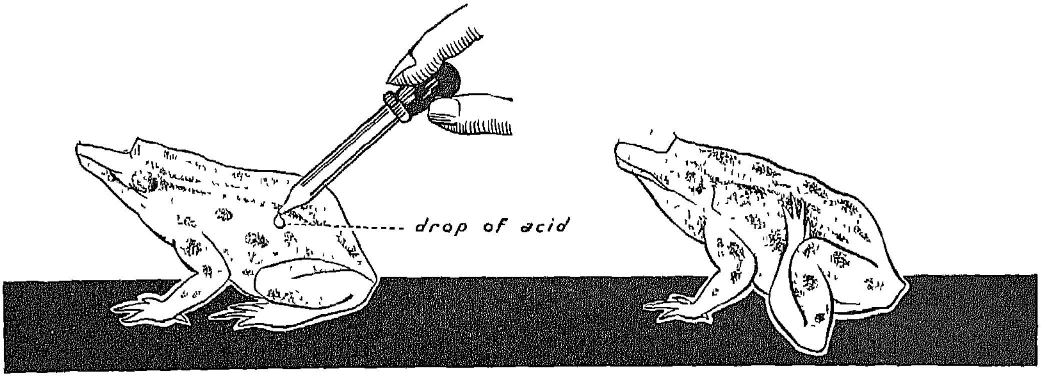


Fig. 25.26. Demonstration of reflex action in a decapitated frog. A drop of acid is placed on the skin of the frog at the left. Its response is shown at the right. After C. Gramet and J Mandel, *Biology Serving You*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1958.

Nerves. Ten pairs of cranial nerves arise from the brain, and an equal number of spinal nerves from the spinal cord (Fig. 25.27).

The cranial nerves coming from nose, eyes and ears (I, II and VIII) are entirely **sensory,** i.e., they bring impulses from the sense organs to the brain. Those leading to the muscles of the eyeball (III, V and VI) are **motor** nerves which carry messages from the brain to these muscles and effect their movements The rest are mixed nerves, having both sensory and motor functions.

The spinal nerves (1-10) arise from the spinal cord and emerge from the vertebral column through the spaces between two consecutive vertebrae. Excluding the first pair which is motor, all the other spinal nerves are mixed. Each of them has two roots—a dorsal sensory root and a ventral motor root (Fig. 25.25).

As shown in figure 25.27, there are two sympathetic nerve cords, one on either side of the vertebral column. These have a series of little swellings or **ganglia** each of which is joined to the spinal nerve by a connecting branch. The sympathetic nerves enter the skull and join some of the cranial nerves. Branches of the sympathetic nerves enter the heart, liver, stomach, kidneys, reproductive organs, urinary bladder, etc , and control the involuntary activity of these organs

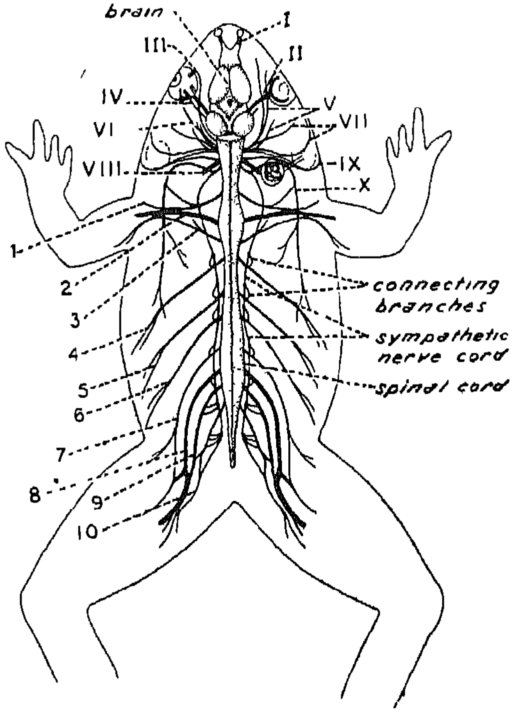


Fig. 25.27. The cranial (I-X) and spinal (1-10) nerves (dorsal view).

Sense Organs

Like man the frog has five special senses. These are the senses of touch, smell, taste, sight and hearing. The impulses or stimuli (changes in the environment) affect the specific sensory structures or receptors in the skin, nose, tongue, eye and ear. The receptors are connected to the sensory nerves, and thus the nerve impulses are transmitted to the central nervous system.

Organs of touch. Receptors for touch (**tactile cells**) are located in the dermis and usually occur in groups called **touch corpuscles.** These are sensitive to touch. Similarly there are other corpuscles which are sensitive to chemical stimuli, and to variations in temperature and humidity.

Organs of smell. The sense of smell dwells in the mucous membrane of the nasal chambers. Some of the epithelial cells are specially provided with delicate processes at their free ends while their inner ends are connected with the fibres of the olfactory nerve. These special cells of the epithelium are called olfactory cells. Minute odorous particles entering the nasal chambers through the nostrils affect these cells. The impulse is then transmitted to the brain.

Organs of taste. Organs for perceiving the sense of taste are called **taste buds** and are located on small papillae of the tongue and the roof of the mouth. The stimulus in this case is supplied by the chemicals contained in the food.

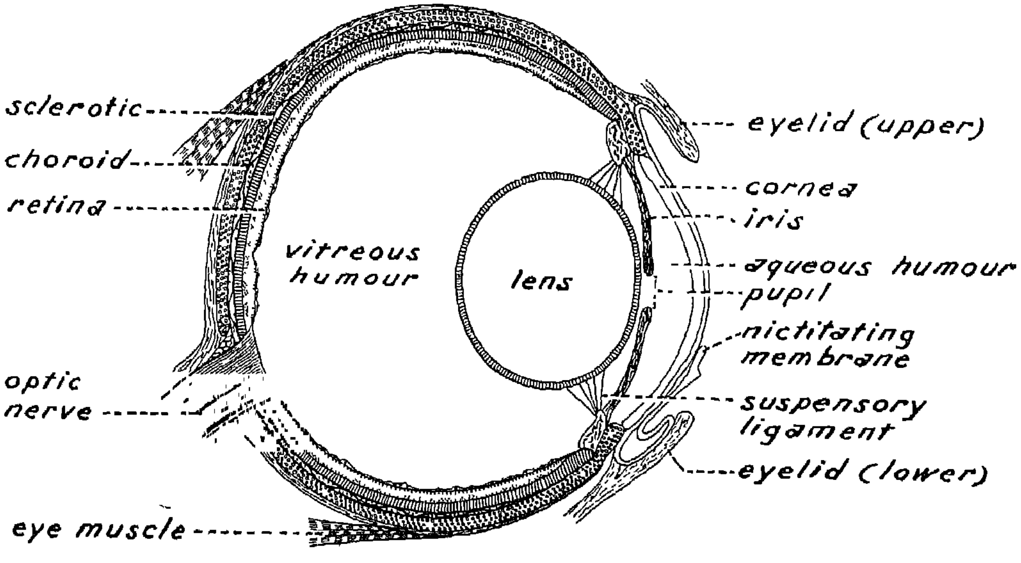


Fig. 25.28. Vertical section of eye.

Organs of sight. Each eye is a more or less globular structure lodged in an orbit of the skull where it can be rotated, elevated or depressed by a set of six eye muscles. The outer exposed part of the eyeball is clear and transparent while its concealed part is opaque. The structure of the eye can be understood from a vertical section (Fig. 25.28). The wall is composed of three layers The outermost whitish **sclerotic layer** is formed chiefly of connective tissue. The middle **choroid layer** has a rich blood supply and is darkly pigmented. The innermost layer or the **retina** is formed of sensory cells. These layers are somewhat modified towards the outer part. The sclerotic layer is continued as a transparent **cornea** which in turn is covered by a transparent continuation of the skin (**conjunctiva**). The choroid layer is separated from the sclerotic layer and forms a vertical sheet (**iris**) in front of the lens. The iris is composed of radiating muscles and has a central opening called the **pupil** which can be reduced or increased. A large transparent spherical body, the **lens,** is situated just behind the iris and is held in position by **ciliary muscles** that are attached to the eyeball. The retina extends only up to the bases of the ciliary muscles.

The lens and the associated structures divide the internal cavity of the eyeball into two unequal chambers. an outer chamber filled with a clear watery fluid (**aqueous humour**) and an inner chamber filled with a jelly-like substance (**vitreous humour**).

The retina (Fig 25.29) is the most sensitive part of the eye. Its inner surface is covered with nerve fibres which converge at the back of the eyeball and form the optic nerve Next to the nerve fibres there are several layers of sensory cells Then there is a layer of light-sensitive element formed by highly specialized cells called **rods** and **cones.** Next to this is a layer of pigmented epithelium. When the light rays enter the eye and fall on the retina, the rods and cones are stimulated and the nerve impulses thus set up are transmitted through the sensory cells and the nerve fibres into the optic nerve. At the point of origin of the optic nerve there are no rods and cones in the retina. This is called the **blind spot** and the part of the image falling on this is not perceived.

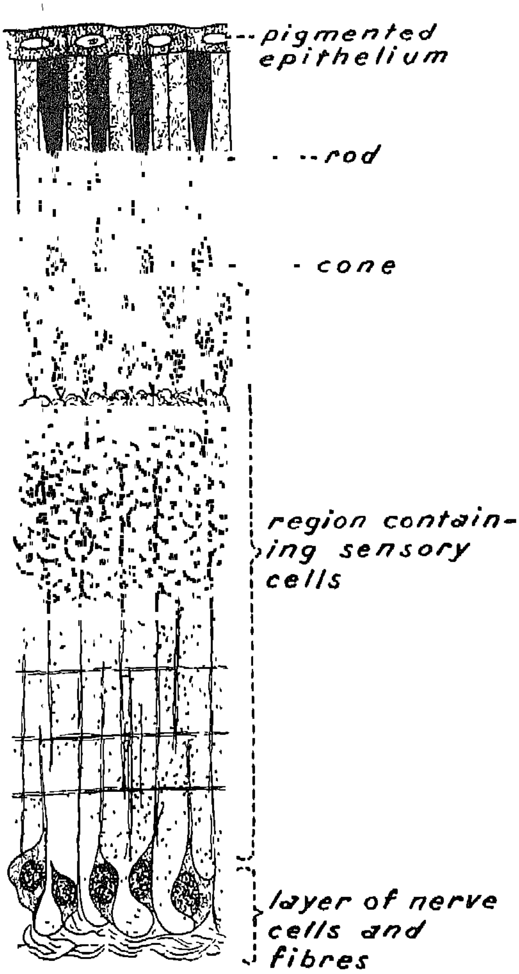

pigmented epithelium
rod
cone
region containing sensory cells
layer of nerve cells and fibres

Fig. 25.29. Vertica section of retina. After T J. Parker, W.N. Parker, B.L. Bhatia and M.A Moghe, *An Elementary Text-Book of Zoology for Indian Students,* Macmillan & Co., Ltd., London, 1957.

The eye is somewhat comparable to a photographic camera. The lens and cornea refract the light rays coming from the object and form an inverted image on the retina. The adjustment to far and near objects is effected by reflex movement of the lens forward and backward. The frog can regulate the size of the pupil (as a reflex mechanism) to admit more light in darkness and less light in strong illumination. The impulses set up in the retina are transmitted to the brain by the optic nerve. Frogs are myopic (i.e. they can efficiently see only near objects) and have only a monocular vision. Nevertheless, they can perceive moving objects quite efficiently.

Organs of hearing and equilibrium. You have learnt earlier about the presence of a tympanic membrane or eardrum. On its inner side is a hollow cavity, the tympanic chamber, which is continuous with the pharynx through the respective **eustachian tube** (Fig 25.30). This arrangement permits the vibration of the eardrum by equalizing the air pressure on the outer and inner sides.

A bony rod (**columella**) is joined to the inner surface of the eardrum. It extends through the tympanic chamber and its other end is fixed to a small oval aperture of the auditory capsule through a cartilaginous nodule called **stapedial plate.**

The auditory capsule contains the delicate internal ear. Its main part is a kind of irregular bag to which are attached three **semicircular canals** lying at right angles to each other. This structure contains a fluid and many minute calcareous floating particles. All around the internal ear there is another fluid which protects it from shocks.

Frogs have a well-developed sense of hearing. Sound waves striking the eardrum set it into vibration. The vibrations are transmitted through the columella and stapedial plate to the internal fluids which ultimately create nerve impulses that are sent to the brain through the auditory nerve.

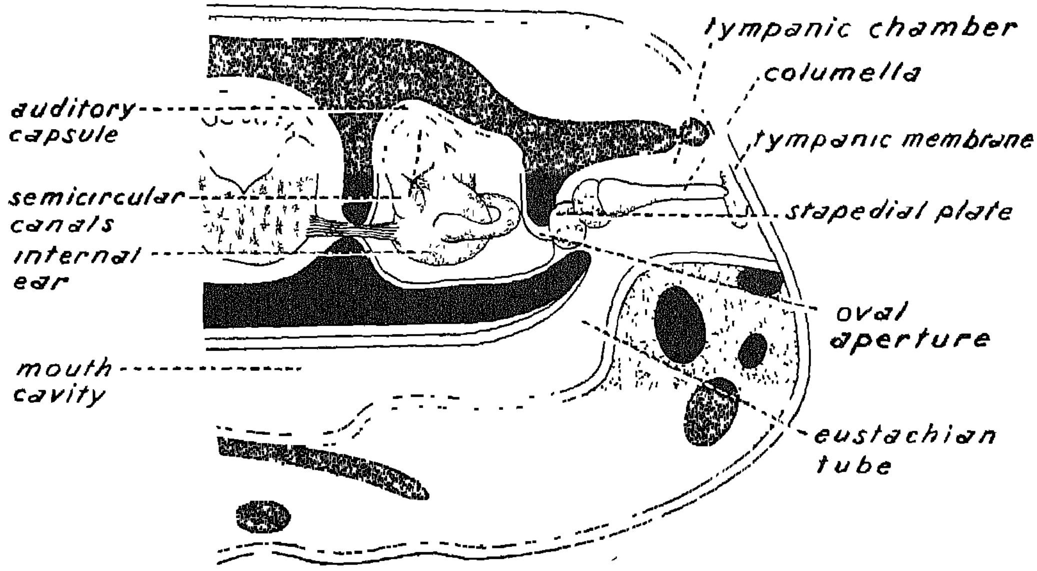


Fig. 25.30. Transverse section through head at the level of the tympanic membrane. Only one half of section has been shown. After T.J Parker, W N Parker, B L Bhatia and M.A. Moghe, *An Elementary Text-Book of Zoology for Indian Students*, Macmillan & Co, Ltd., London, 1957

The internal ear is also responsible for the equilibrium of body both during rest and locomotion. The calcareous particles press upon the sensory hairs in the lining of the internal ear in a particular way Whenever the plane of the body is changed, the pull on these particles is accordingly altered and the sensory hairs are stimulated in a different way. The different impulses, thus set in, are communicated to the brain and the animal is able to readjust to a normal position The fluid in semicircular canals directly stimulates the sensory hairs

Excretory System

In all animals the body cells produce certain waste substances which need to be eliminated These substances may be gaseous such as carbon dioxide, or dissolved solids such as urea. Carbon dioxide is eliminated through the skin, lungs and the lining of the mouth cavity The liver converts the toxic, nitrogenous solid wastes of the body (brought to it through the blood) into simple soluble non-toxic substances such as urea These are finally removed by the kidneys in the form of urine. The kidneys and associated structures, namely, a pair of ureters, a urinary bladder and cloaca constitute the main parts of the excretory system (Fig. 25.32).

The **kidneys** are a pair of elongated, reddish-brown structures located in the abdominal cavity From the posterior outer edge of each kidney runs a tube called **ureter**. Both the ureters open into the cloaca.

The kidney is made up of a tangled mass of highly twisted, microscopic tubes (the **urinary tubules**) and a large network of blood vessels and capillaries (Fig. 25 31 A). The urinary tubules are the functional units of the kidney. The structure of a urinary tubule is shown in figure 25.31 B. The tubule is lined with a ciliated epithelium. The soluble excretory substances like urea, uric acid and salts of potassium, sodium, calcium and magnesium are brought to the kidneys by the renal arteries. Filtration of blood takes place in the capsule at one end of the tubule. All the substances present in the blood, except proteins and red blood cells, are filtered down. Useful materials like sugar, salts of sodium, and plasma are reabsorbed by the capillary

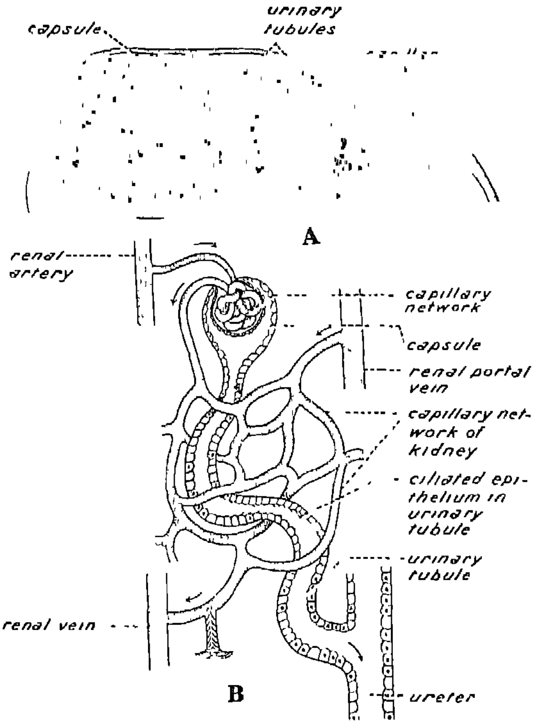


Fig. 25.31. A. Transverse section of kidney. The tangled masses are the urinary tubules. B. Diagram of a single urinary tubule with its blood capillaries. After T.J Parker, W N. Parker, B L. Bhatia and M A. Moghe, *An Elementary Text-Book of Zoology for Indian Students*, Macmillan & Co , Ltd , London, 1957.

network while the rest of the excretory products flow down the tubule as urine, the current being kept up by the beating of cilia. The urine collects in the **urinary bladder** which is emptied at intervals Besides this important function of removing waste substances, the kidneys regulate the quantity of water in the frog's body.

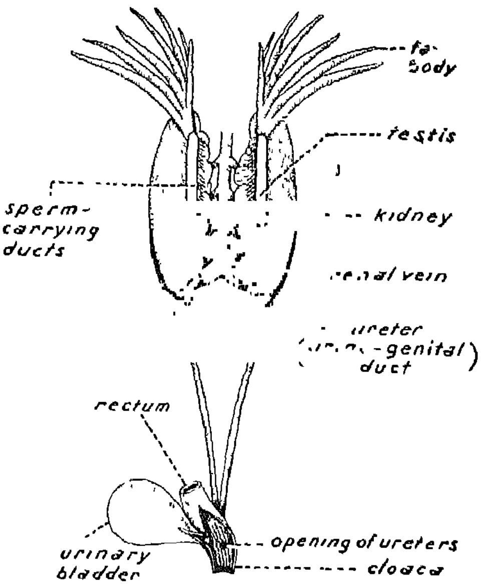


Fig. 25.32. Reproductive and excretory systems of a male frog.

Reproductive System

The male reproductive organs include a pair of testes and numerous sperm-carrying ducts (Fig 25.32). The two kidneys and ureters are also involved and act as helping reproductive organs The **testes** are elongated, light-yellow bodies attached to the ventral side of the kidneys. Each testis is composed of numerous microscopic **seminiferous tubules** (Fig. 25.33 A and B). The germinal epithelium of each tubule produces groups of spermatozoa. When ripe, the spermatozoa begin to float in the fluid of the tubules. Each spermatozoon has a head (largely the nuclear part) and a tail (of cytoplasm, Fig. 25.33 C) Numerous delicate ducts arise from each testis and convey the spermatic fluid into

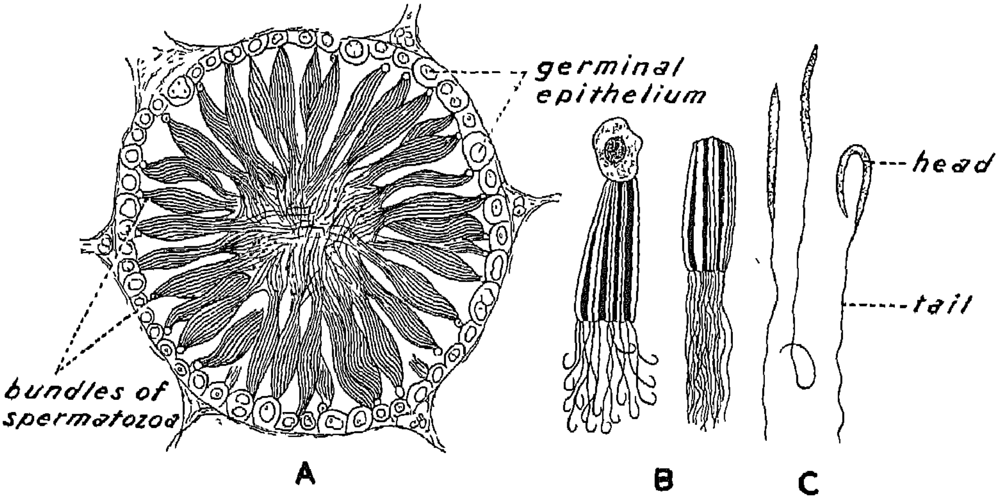


Fig. 25.33. A. Transverse section of one seminiferous tubule of the testis enlarged. B. Stages in the development of sperms. C. A few spermatozoa. After T J. Parker, W N. Parker, B.L. Bhatia and M.A. Moghe, *An Elementary Text-Book of Zoology for Indian Students*, Macmillan & Co., Ltd; London, 1957.

the kidney. The spermatic fluid is then conveyed to the ureter (which can also be termed urinogenital duct) from where it is discharged The male frog has no copulatory organ.

The female reproductive organs are a pair each of ovaries and oviducts (Fig 25 34 A) The **ovaries** are large, irregularly lobed bodies attached to the dorsal body wall and located very close to the kidneys. During the breeding season the ovaries become enlarged, and fill up a greater part of the abdominal cavity. The surface of each ovary shows numerous little rounded bodies, the **ovarian follicles,** each of which encloses an egg (Fig 25.34 B). The egg contains a nucleus and yolk granules (nourishment for the embryo) When the eggs are mature, they break through the ovarian wall and fall into the body cavity. Gradually they reach the funnels of the **oviducts** close to the lungs. Passing down the highly convoluted part of the oviduct the eggs are temporarily stored in the last portion of the oviduct called the **uterus.** The walls of the oviduct are glandular and produce a jelly which surrounds each egg during its passage. The uterus of each side opens into the cloaca.

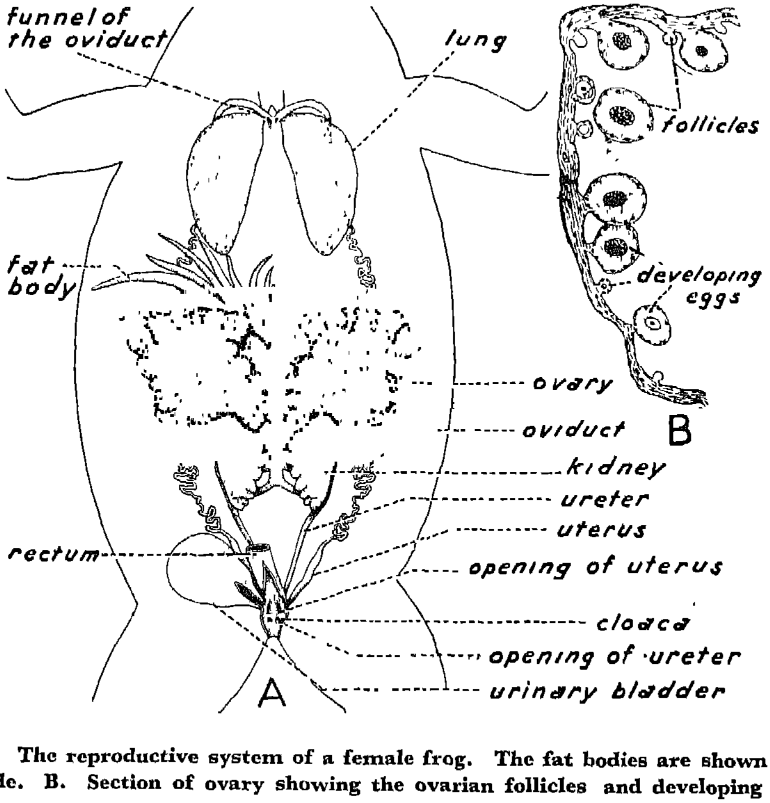


Fig. 25.34. A. The reproductive system of a female frog. The fat bodies are shown only on one side. B. Section of ovary showing the ovarian follicles and developing eggs.

Associated with the reproductive organs are yellowish tufts of tissue called **fat bodies.** They serve to store fat. During hibernation the animal draws its nourishment from them.

Spawning, Fertilization and Development

In the breeding season the male and female frogs come out in pairs. The male frog climbs the back of the female and holds her firmly behind the fore-limbs. This process is called **copulation**. The copulation pads on the fore-limbs of the male become specially swollen during breeding season and help him in keeping the grip. The pair may remain in this position for several hours or even days, until the female passes out a mass of eggs (spawn) through her cloaca into the water. Simultaneously, the male sheds his spermatic fluid. The spermatozoa swim actively around the ova in millions but only one succeeds in penetrating each egg. The tail is left behind and the head fuses with the nucleus of the egg. The fertilized egg is the zygote, and marks the beginning of a new individual.

The jelly absorbs water and swells up. It helps the spawn to float on the surface of water and to stick to nearby objects so that the eggs are not washed away. The jelly also prevents the entry of other organisms into the egg, and being distasteful, it saves the eggs from being eaten up by other water animals. Every egg in the spawn can rotate freely in its surrounding jelly. The dark, pigmented half (**animal pole**) of an egg always remains upwards while the whitish half (**vegetal pole**) faces downwards (Fig. 25.35).

Within two to three hours after fertilization the zygote undergoes repeated divisions to form a hollow ball of cells (Fig. 25.35). This hollow ball changes into a two-layered cup by invagination. The outer layer of cells is the ectoderm and the inner, the endoderm. A third layer, called mesoderm, is then formed between these. The three germinal layers give rise to all body structures. Now the developing frog or the embryo elongates. Its anterior end becomes rounded and forms a sucker. A tail begins to form at the posterior end. A mouth is formed above the sucker and an anal opening develops below the tail. Two pairs of gills arise on the sides of the head. With these changes the embryo becomes a **tadpole** which now breaks through the jelly and swims freely in water like a fish, or attaches itself to some water-weeds on which it feeds.

Metamorphosis of tadpole. The actively swimming tadpole is quite different from the adult frog both in structure and behaviour. In fact, a layman would hardly believe that the tadpole is the young

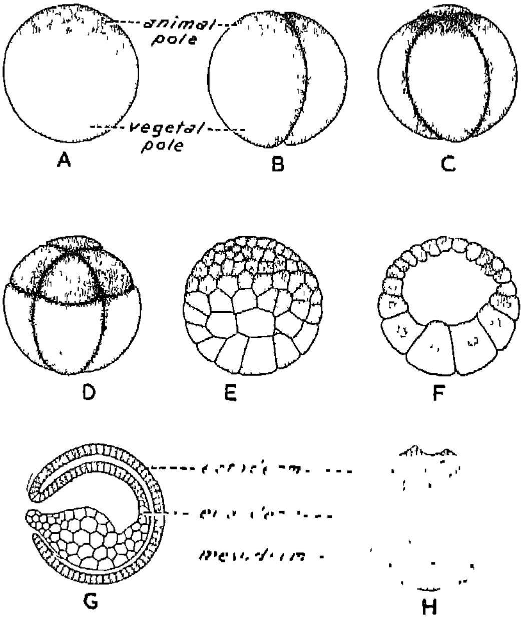


Fig. 25.35. Early development of frog. A. The fertilized egg showing the animal and vegetal poles. B, C and D. Two-, four- and eight-celled stages in the divisions of the fertilized egg. E and F. Hollow ball of cells, entire and in section. G. Section of the two-layered cup stage. H. Section of embryo showing mesoderm.

one of a frog. An immature stage of this kind which moves, feeds and grows, but is sufficiently different from the adult, is called the **larva.** The changes which a larva undergoes in order to become an adult are collectively termed **metamorphosis.**

The two-week old tadpole undergoes many remarkable changes It stops feeding The mouth becomes wider and teeth are formed The gills begin to shrivel, and the animal now breathes only by the lungs and skin. The tail begins to

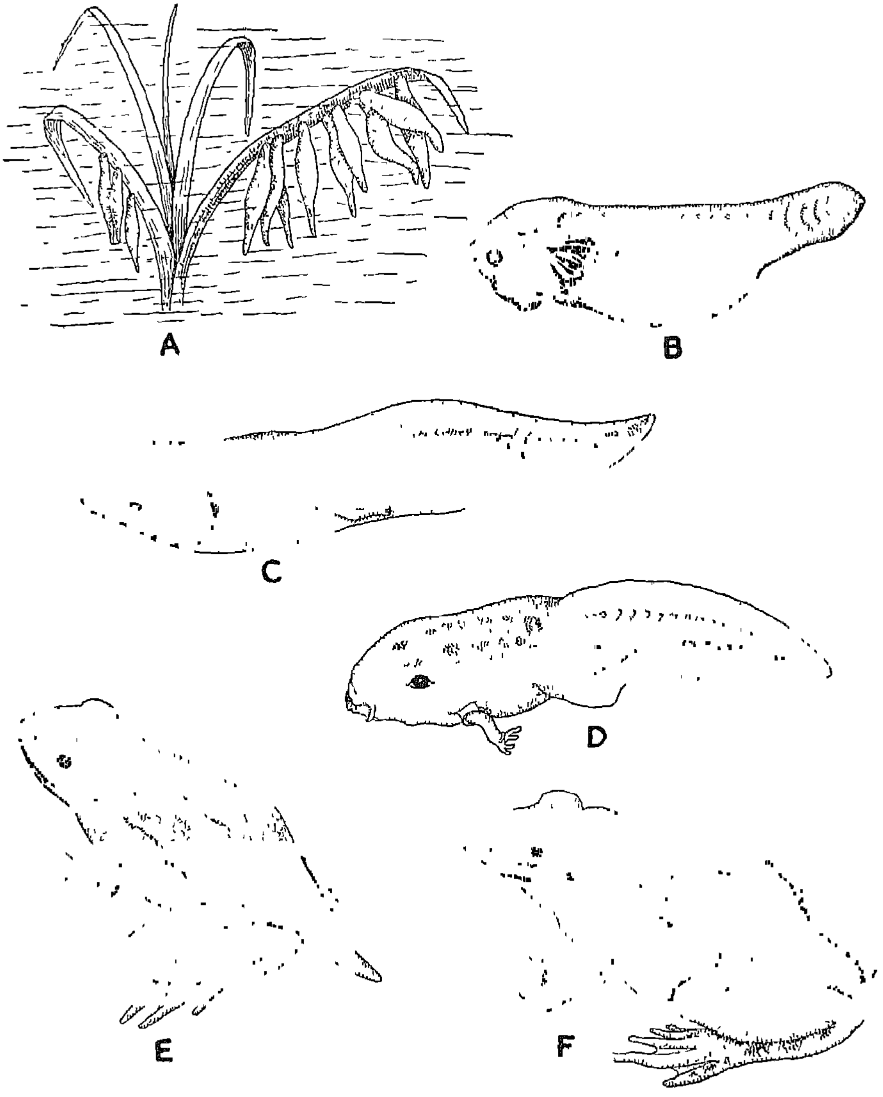


Fig. 25.36. Stages in the development of adult frog from the tadpole stage.

shrink and its substance is utilized to nourish the rest of the body (Fig. 25.36) Feeding is resumed but now on animal diet By this time the limbs have become fully developed These tiny frogs (still with a vanishing remnant of the tail) begin to move on land The entire development, from fertilization to the young frog, takes about three months

You have seen from the above account that a tadpole is very much like a fish in its structure and behaviour This supports the view that the frog has descended from fish-like ancestors In other words, the life history of the frog reflects its evolutionary history. Such a view has been called the **recapitulation theory.** You would read in Section VI that some fish-like stages occur in the development of even the higher vertebrates, including man.

SUMMARY

The amphibians are cold-blooded vertebrates most of which lead a double life. In their early life they are fish-like creatures called tadpoles that swim about in water and breathe by means of gills In their later life they can live on land and breathe by means of lungs. Frogs, toads and salamanders are common examples of this group.

Frog, a favourite animal for detailed study of the vertebrate body, is a soft, slimy creature with a streamlined body. It has two pairs of unequal limbs and protruding eyes. The hind-limbs are webbed. The elastic tongue is attached in front, and is flipped out and withdrawn very rapidly while catching the insects.

The frog uses its skin, the lining of the buccal cavity and the lungs as organs of respiration The males can use the outgoing air for croaking.

The frog's heart is three-chambered and there is some mixing of the oxygenated and deoxygenated bloods in the ventricle. The blood leaves the heart by way of arteries and returns through the veins. The blood from the hind part of the body returns indirectly by way of the renal portal and hepatic portal systems.

The two kidneys form the chief excretory organs. The ureters collect urine from them and open into the cloaca. The ureters also serve to transmit the spermatozoa.

There is a central and a peripheral nervous system, functioning in a unified manner The central nervous system consists of the brain which is protected in the brain box, and the spinal cord which is contained in a canal formed by the vertebral column The peripheral system consists of 10 pairs of cranial nerves which are either sensory or motor or mixed, and 10 pairs of spinal nerves which are all of the mixed type

The sense organs consist of the smelling, visual, hearing, touch, taste and balancing structures. There are several endocrine glands which control the various functions of the body through their secretions.

Mating in frogs, as also in most other amphibians, occurs in water. During this process clusters of eggs surrounded by jelly are squeezed out of the cloacal opening of the female Almost simultaneously, the male sheds the spermatic fluid over the eggs and fertilization takes place soon after.

The fertilized eggs develop into fish-like tadpoles which feed on the young leaves of aquatic plants and breathe by gills The tadpoles gradually metamorphose into adult frogs which hop about on land. During severe cold the frogs burrow deep into the ground and hibernate.

QUESTIONS

1. How does the frog protect itself from its enemies?
2. Do you think frogs would be at a disadvantage if they had scales on their skin?
3. What are the functions of the skeletal system? Is an internal skeleton more advantageous than an external skeleton?
4 Enumerate the differences between arteries and veins
5. What is the significance of the hepatic portal system?
6. How does the ear act both as a hearing and a balancing organ?
7 In what way does the tadpole of a frog resemble a fish? How does it differ?
8 Define the terms larva and metamorphosis.
9. How does a frog catch a flying insect?
10. Why do amphibians always lay their eggs in water?
11. Some people claim that they can 'show' you frogs being produced from mud. What do you think about these claims? How will you convince such people to the contrary?
12 What is a reflex act? Give three common examples of such acts.

FURTHER READING

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CHAPTER 26

Reptiles—The Scaly Creeping Vertebrates

THE reptiles are cold-blooded vertebrates usually with an elongated, low-statured body creeping or crawling on the ground (L. *reptare*= to creep). You have surely seen a number of such animals as the lizards, snakes, pythons, tortoises and crocodiles. Several of them have frightening looks and some are really poisonous and dangerous. About 4000 different species of reptiles are found today and a still larger number seems to have existed some 200 million years back. That period was called the age of reptiles; and huge dinosaurs, some of which were several times bigger than the modern elephant, roamed on the land and swam in the waters. Among the largest reptiles of today are the 'komodo dragon' (a lizard) of Indonesia, the crocodiles, alligators, pythons and giant turtles.

General Characters

The reptiles are easily distinguished from other vertebrates. They have a dry skin covered with scales The scales frequently come off intact in the form of cast-skin, as in the snakes and lizards. The hands and feet have claws. The ventricle of the heart is partially divided into two by an incomplete septum, but this division is complete in the crocodiles. The lungs are well-developed in the young (there is no larval stage) and the reptiles never breathe by gills. Comparing the body characters of the reptiles with those of the amphibians you can easily see that the former are better suited for life on land.

The reptiles consist of many groups. Of these, four main groups are living today. These are the lizards and snakes, turtles, crocodiles and tuatara. Among the reptiles of the past, the dinosaurs were the most interesting.

Lizards and Snakes

The lizards are found everywhere in warm climates. The common house lizard or the wall lizard is familiar to all. By means of its vacuum-cupped toes it easily sticks to the walls and ceilings. You may have seen a lizard break its tail and the broken portion twitching for a short while This self-breaking is a method of protection from the enemy whose attention is diverted to the separated part while the lizard escapes. A new tail may grow from the broken end. This process is known as **regeneration.** The regenerated tail contains only a single

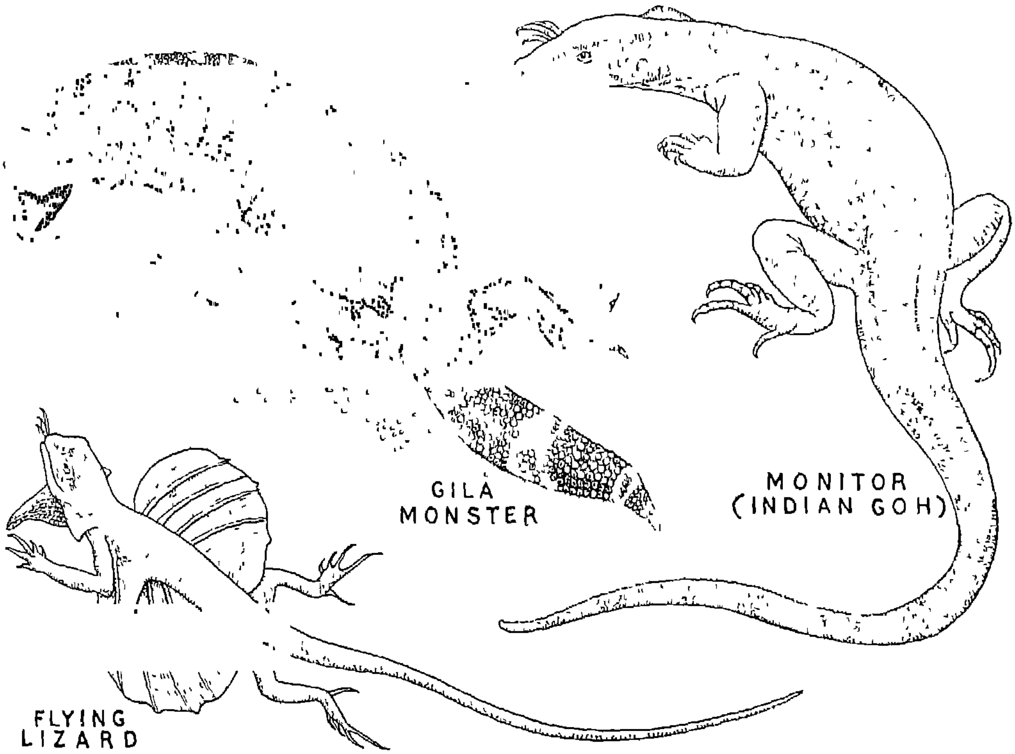

Fig. 26.1. Some common lizards; of these only the gila monster is poisonous. After J Z Young, *The Life of Vertebrates*, Clarendon Press, London, 1950

rod-like prolongation from the last vertebra at the broken end

Other common Indian lizards are the monitor (Indian goh), flying lizard, gila monster (Fig. 26.1), and the chameleon (Fig 26.2). The last named is known for its capacity to change the body colour in harmony with the surroundings. It has a long, shooting tongue to catch its prey, and long powerful tail to anchor round the twigs. The flying lizard has thin, wing-like expansions of the sides of the body supported by long ribs The expansions help the animal in soaring through the air from tree to tree

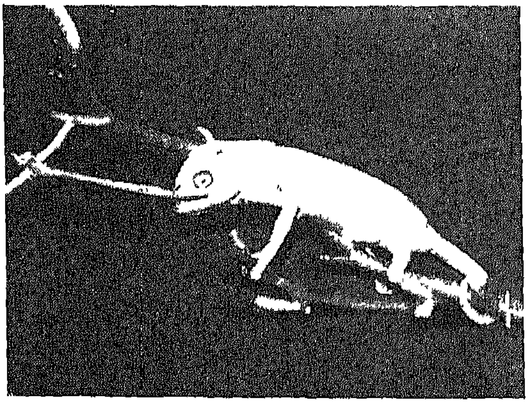

Fig. 26.2. The chameleon, another common lizard well-known for its ability to assume bright colourations. With its long tongue it can effectively catch insects.

Almost all the lizards are non-poisonous Most of the prevailing stories about lizard poisoning are not true The only two poisonous lizards are the gila monster and a near relative of this, found in North America. They have a poison gland and grooved teeth for injecting the poison. Their bite can kill a man.

Certain lizards have no legs and look like snakes, but by the presence of ear-openings and the movable eyelids you can easily tell them apart from the snakes (Fig. 26 3)

The snakes are reptiles which have completely lost their limbs. They crawl by winding their body from side to side, usually pushing against the irregular surfaces. The broad scales on the belly and strong muscles assist in the movement The snakes have no eyelids, but each eye is covered over by a transparent membrane The ear lacks any external opening and the internal ear lies imbedded in the skull. Thus snakes cannot hear sounds carried through the air but they do perceive certain vibrations from the ground carried to the ear through the bones of the skull. The snake-charmer's music on the pipe is more to please the audience rather than to please the cobra (Fig. 26.4) The cobra is deaf. It sways its hood largely in

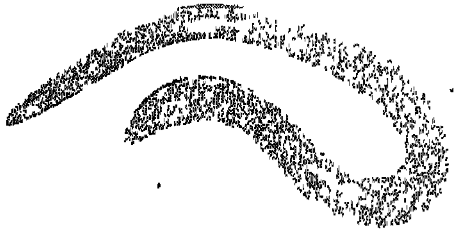

Fig. 26.3. A limbless lizard. The absence of limbs gives it a worm-like appearance.

Fig. 26.4. A snake-charmer. The belief that the music from his pipe charms the cobra is erroneous as this animal is deaf.

response to the movement of the snake-charmer's pipe

Snakes have a strong sense of smell Have you ever seen the long, forked tongue of a snake? It is repeatedly protruded and in so doing it carries the smell-bearing particles to the special sense organs in the roof of the mouth, thus helping the animal to smell its surroundings.

Snakes feed mostly on insects, frogs, toads, lizards, squirrels, nestlings (young birds) and other animals They catch their prey alive and swallow it whole, without chewing Because of the elasticity of their jaws snakes commonly swallow a prey which is even bigger than the diameter of their own mouth The teeth serve only to prevent the prey from slipping out during swallowing. The poison teeth or **fangs** are specialized long teeth with a groove through which the poison is injected (Fig. 26 5) The fangs and the poison gland are present only in a few kinds of snakes

Snakes are found practically all over the world but they are more abundant in the tropics. Most snakes live on land, inhabiting burrows in the ground. Some live in freshwater and a few even in the sea. The freshwater snakes are non-poisonous but those living in the sea are deadly You can identify a sea snake by its laterally compressed tail (Fig 26.6).

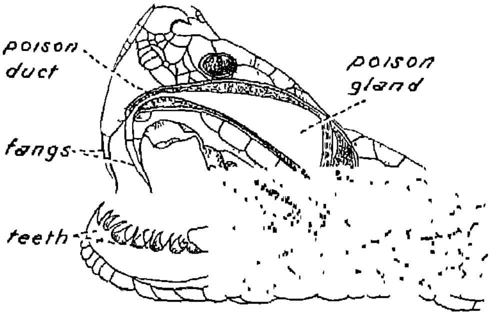

Fig. 26.5. The poison gland, fangs and ordinary teeth of a snake. Modified from E Kroeber, W H. Wolff and R L. Weaver, *Biology*, D.C. Heath and Company, Boston, 1960

Most snakes are non-poisonous and harmless The rat snake or 'dhaman' is one of our commonest non-poisonous snakes (Fig 26 6). This and many others, like the grass snakes and pythons, do us great service by eating many harmful pests such as rats, rabbits and other animals which damage our crops Some of the pythons are fairly large, reaching a length of about 10 metres. They are prized for their beautiful skin which is used for making ladies' purses and shoes. The so-called double-headed snake or 'dumai' is a kind of small python Its blunt tail gives the false appearance of another head. The pythons have a vestigial hip girdle.

Our commonest poisonous snakes are the cobra, krait and Russel's viper The cobra is identified by its hood There are several well-known species of cobra of which the king cobra is the deadliest. It is found in certain parts of Bengal, Bihar and Orissa. The kraits are beautifully coloured with black and yellow bands (Fig 26.6). The vipers have strong swellings on the sides of the head near the neck. The poison (venom) of the snakes is a modified salivary fluid. It may act either on the nervous system (as in cobra) or on the blood system (as in viper). It has been estimated that about 5000 persons die of cobra-bite in India every year. After giving some first-aid (cutting open the wound, sucking the poison, putting potassium permanganate and applying tourniquet) to the victim of snake-bite, an antivenin injection is the best treatment. Antivenin is a biological product obtained from the blood of immunized horses. In

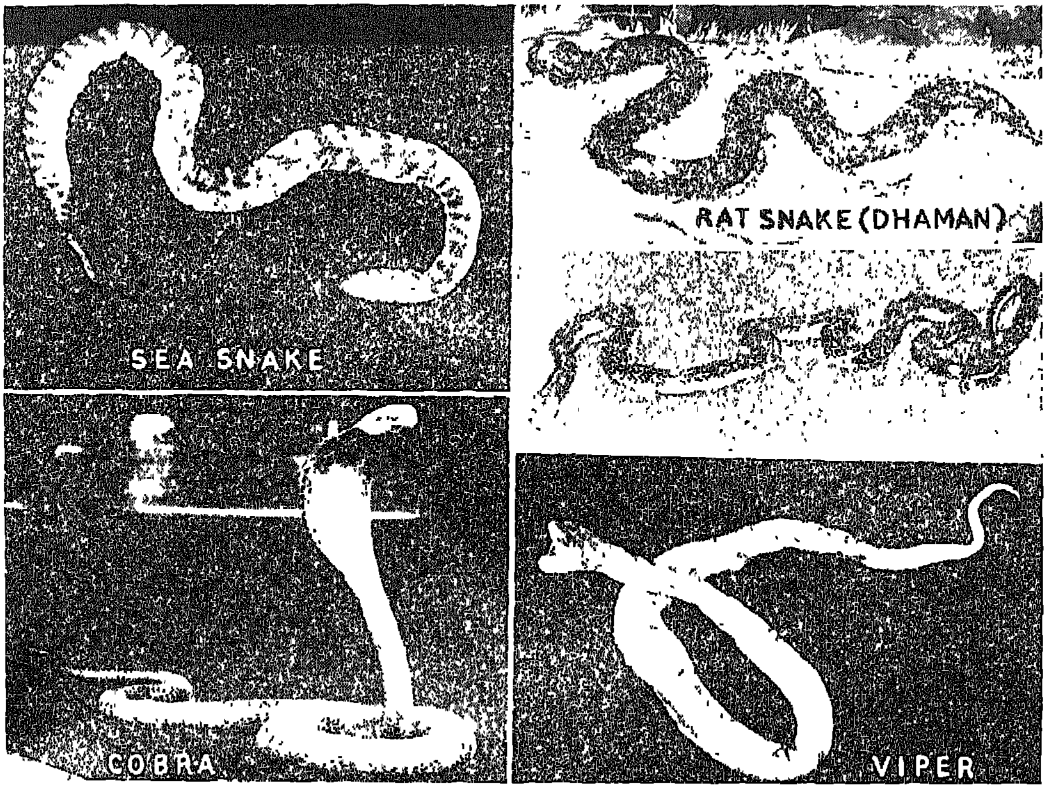

Fig. 26.6. **Some common kinds of snakes. The sea snake, cobra, krait and viper are poisonous.**

India, this medicine is produced chiefly at Kasauli (Simla Hills) and in the Haffkine Institute, Bombay.

Tortoises

The tortoises (Fig. 26 7) have developed a bony case or shell to protect their body The head, neck and the limbs can be withdrawn into the shell They have no teeth, but possess a powerful horny beak. They live on land and in freshwater, and have simple limbs with which they can walk on land. Certain freshwater tortoises are edible, and are sold under the name 'terrapin'. Turtles are marine forms with their fore- and hind-limbs shaped like flippers which are helpful in swimming. The aquatic forms lay their eggs on sandy banks. The eggs are large, have calcareous shells and resemble those of hens and swans.

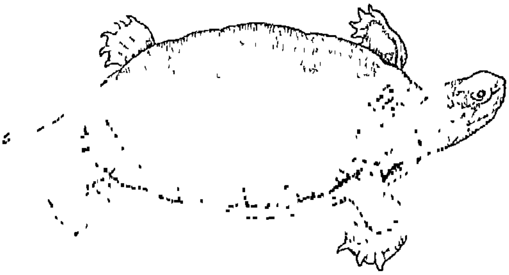

Fig. 26.7. **The common tortoise. The animal is well protected in its armour of bony plates. It is believed to have the longest span of life among all the living animals.**

Crocodiles

The crocodiles are very large but lizard-like reptiles (Fig. 26.8). Their skin is thick and leathery with some strong, bony internal plates. The jaws are extended into a long snout. In the Indian gavial, commonly called the 'gharial', the snout is long, narrow and sword-like. One species of the gavial is common in the river Ganga.

The American alligators are large and have a broad, round snout while the common crocodiles have a pointed snout with a small notch in the upper jaw. The hides of crocodiles and alligators are in great demand for the manufacture of purses, suit-cases, shoes and other articles.

All crocodilians are carnivorous. The alligators and common crocodiles sometimes attack man. The gavial feeds on fish.

The crocodiles are the most advanced of the reptiles in that they have a four-chambered heart with completely partitioned

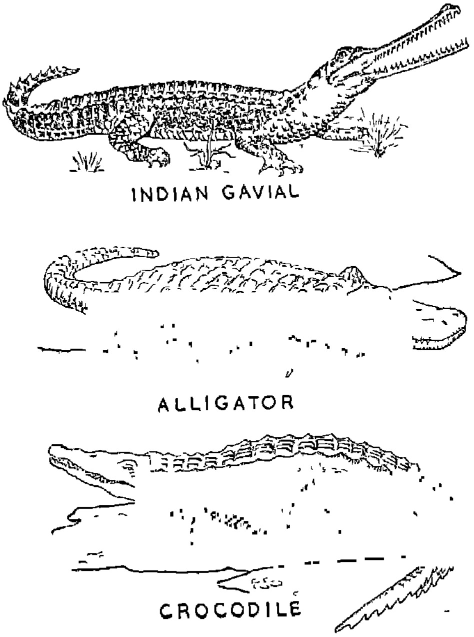

Fig. 26.8. The crocodiles. They lay their eggs, nearly 50 at a time, on the banks of streams, and cover them with a mound of mud and leaves. When the eggs hatch, the mother opens the mound. From various sources.

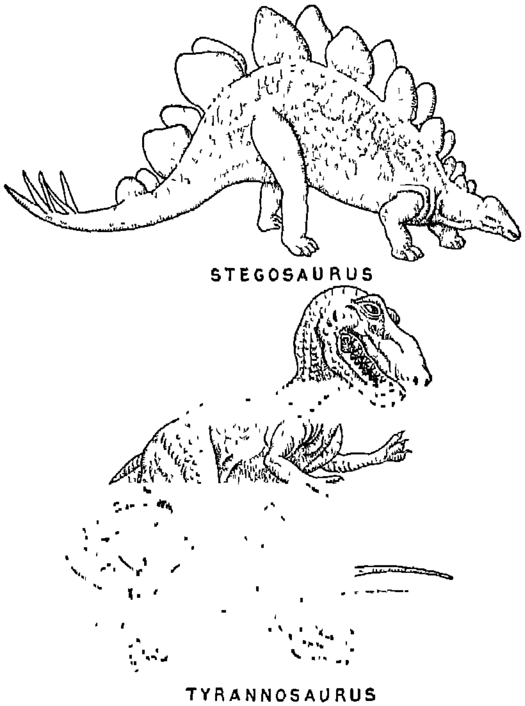

Fig. 26.9. Two of the dinosaurs, massive reptiles of the past. *Stegosaurus* was a herbivorous reptile provided with a horny beak, protective spines, plates and horns. *Tyrannosaurus* was a terrible carnivorous dinosaur sometimes as much as six metres long. After J. Fisher, J Huxley, G Barry and J. Bronowski, *Nature*, Rathbone Books Limited, London, 1960, and W.F. Pauli, *The World Of Life A General Biology*, Houghton Mifflin Co., Boston, 1949

ventricle. The oxygenated and deoxygenated bloods, therefore, remain separate.

Tuatara

The tuatara or *Sphenodon* is a strange lizard-like animal found presently only on a few islands near New Zealand. This ancient reptile is supposed to be even older than the dinosaurs. It is fast becoming scarce and there is a fear that it may disappear altogether. It is about 0.7 metre long and has a third median eye on the top of the head.

Giant Reptiles of the Past—the Dinosaurs

The word dinosaur means a 'terrible lizard', and that was really true of many of them They existed about 100-150 million years back, and were often massive animals which lived in water most of the time. Though man did not exist at that time, he would look no more than a small toy beside the giant dinosaurs. Many fed on water plants which they consumed to the extent of 200 kg a day There were also some carnivorous giant forms, such as the ferocious *Tyrannosaurus*, the king of dinosaurs (Fig 26 9).

SUMMARY

Reptiles include lizards, snakes, tortoises, alligators and crocodiles. Excepting snakes, which are limbless, the other members have clawed limbs. They all have a dry, scaly skin and breathe by means of lungs. Reptilian eggs are large and protected with shells. The ventricle of the reptilian heart is incompletely divided; only in crocodiles this division is complete. The dinosaurs were reptiles which existed in the distant past. Many of them were gigantic The tuatara of New Zealand is the living relic of a very ancient stock of reptiles.

QUESTIONS

1. Which are the four major groups of reptiles represented in the world today?
2. What facts support the conclusion that the reptiles are suited primarily for a life on land?
3. Name the commonest poisonous snakes of India. How do we distinguish a poisonous from a non-poisonous snake?
4. Why do biologists consider the crocodile's heart to be of an advanced type?
5. Name some common lizards of your area.
6. Snakes and worms look very similar. Why do biologists then place them in different groups?
7. Devise an experiment to prove or disprove the common notion that snakes 'dance' to the tune of the snake-charmer's music.
8. What are the common first-aid measures against snake-bite?
9. How will you distinguish a lizard from a salamander?

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CHAPTER 27

Birds—The Feathered Vertebrates

BIRDS are the easiest animals to recognize. They possess feathers on the body and are adapted for flight. The fore-limbs are modified into wings. There are, however, a few birds which have partly or wholly lost the power of flight The ostrich and kiwi can only walk on land

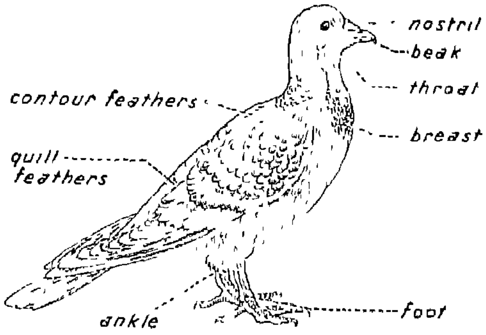


Fig. 27.1. External features of a typical bird.

General Characters

All the birds of the world, wherever they live and whatever they eat, have many common characters which are as follows

The entire body is covered with feathers (Fig 27.1). The **contour feathers** cover the general surface and keep the body warm. The long **quill feathers** occur only on the wings and tail, and help in flight The feathers of most birds are beautifully coloured

The head is prolonged into a beak. A pigeon's mouth for instance, has no teeth but only a horny beak. The shape and size of the beak differ in various birds (Fig. 27 2) and often indicate the kind of food which the particular bird takes. Slit-like nostrils are present towards the base of the beak. The digestive tract of the bird is rather peculiar in having two additional organs, the crop and the gizzard (Fig. 27.3) The **crop** is an extensible sac attached to the oesophagus at the base of the neck The food is swallowed whole and is stored in the crop where it is also softened In the first part of stomach the food is mixed with gastric juice and is then passed on to the second part, the gizzard. The **gizzard** is a thick, muscular sac, lined with rough horny tissue and contains small pieces of stones (which the bird swallows along with the food). Here the food is thoroughly ground. Thus the gizzard performs the function of teeth. The power of sight is remarkably strong. Each eye has a third eyelid which can be drawn over it from the inner angle outward. There are no projecting ears but only apertures leading to the eardrums. These apertures are usually concealed by the feathers. The long and flexible neck enables the birds to rotate their head in all directions.

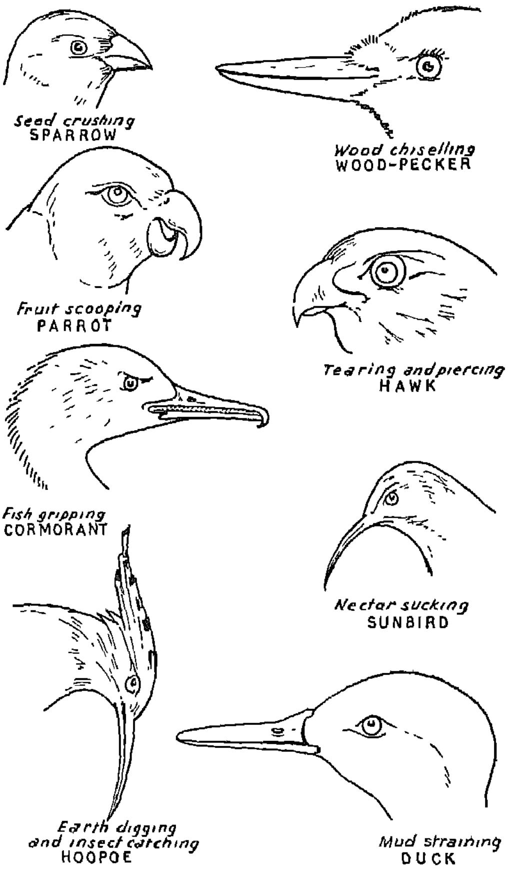


Fig. 27.2. A variety of beaks suited to the particular modes of feeding of birds. After Salim Ali, *The Book of Indian Birds*, Bombay Natural History Society, Bombay, 1964.

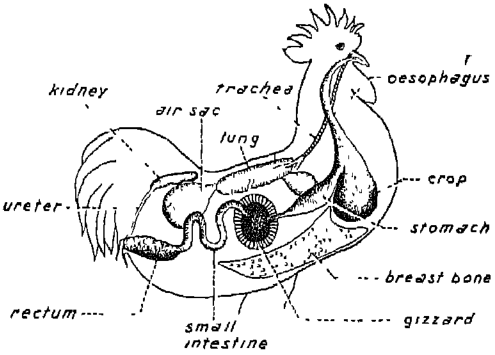


Fig. 27.3. The alimentary canal of a bird with some other associated structures.

As already mentioned, the wings are specialized fore-limbs. Their bones are similar to those in the fore-limbs of frog or man. In pigeon, a row of 23 large feathers in each wing form a compact surface to push the air during flight. The movement of the wings is brought about by powerful flight muscles or 'breast muscles' attached to the large breast bone.

In the hind-limbs, the thigh and the shank are short and very close to the trunk. The foot has an elongated ankle. This part is featherless and covered with scales. In pigeon there are four toes of which the first toe is directed backward. Like the beaks, the feet of birds are also highly varied (Fig. 27.4). Looking at these, you can form a general idea about the mode of living of a bird. Perching foot, as in sparrow, has a device by which the toes are firmly held round the twig automatically on account of the bird's own weight. Such birds can even sleep while perched on twigs without the risk of falling down.

All the birds have a light body. The lightness is mainly due to the presence of spongy bones and thin air sacs in the body. Birds lead a very active life and have a constant body temperature (warm-blooded). Their heart is four-chambered and beats faster than that of other animals. The female birds have only one ovary and only a single egg develops at a time. The eggs are covered by calcareous shells, which are often beautifully coloured. The eggs are incubated by the bird at a more or less constant temperature (of its own body), usually in a nest.

Variety in Birds

Birds include a large variety of forms which can be divided into two main groups, the flightless or running birds and the flying birds.

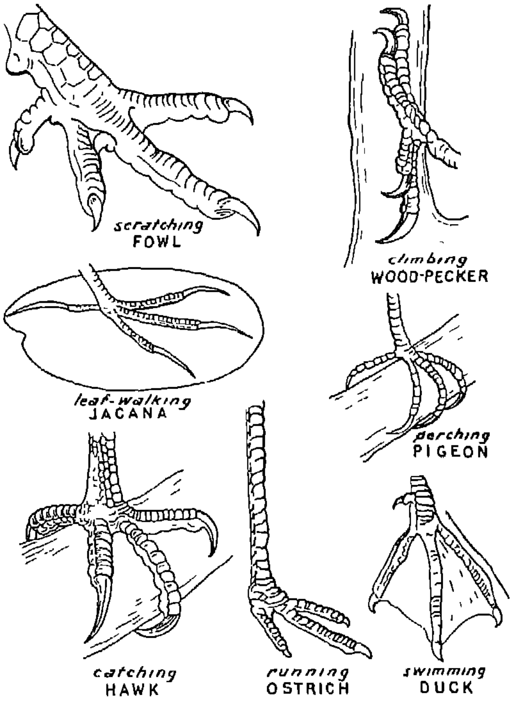


Fig. 27.4. Some adaptive variations in the feet of birds. After Salim Ali, *The Book of Indian Birds*, Bombay Natural History Society, Bombay, 1964

Flightless birds. These are usually large and have long legs. Their wings are reduced and their feathers are curly. The African ostrich (Fig. 27.5) is a huge bird with only two toes in each foot It can run quite fast Its beautiful feathers are greatly valued. On an average the ostrich weighs about 125 kg and its egg equals the bulk of 18 eggs of a hen. The emu of Australia has three toes in each foot Both ostrich and emu are common in zoos The kiwi of New Zealand (Fig 27.5) is also a small flightless bird. The famous penguins (Fig. 27. 6.) living in cold sea waters of the South Pole have their wings modified into swimming paddles. The domestic fowl and domestic duck have also lost the power of flight.

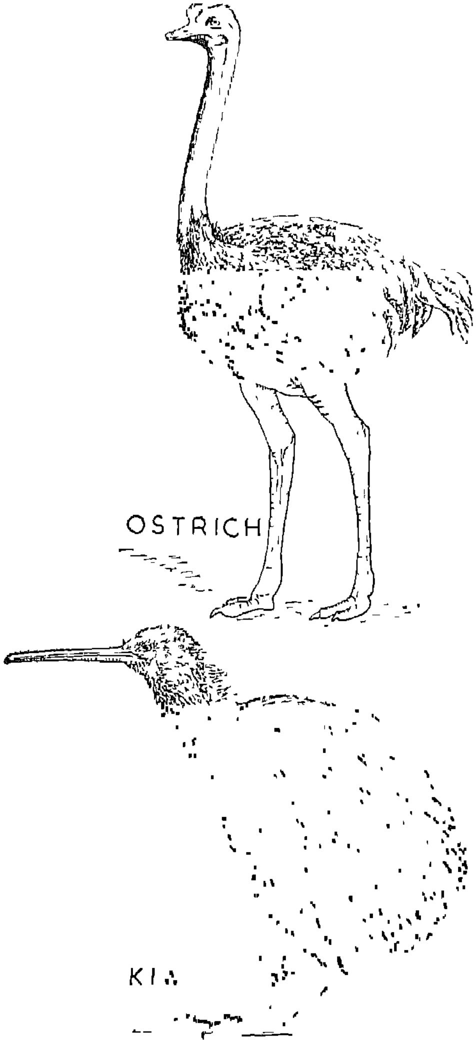
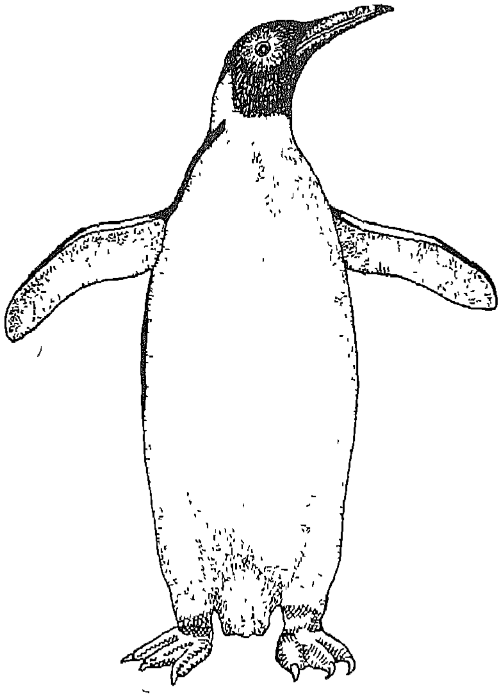


Fig. 27.5. The running or flightless birds. The ostrich has small wings and long legs. It may outrun a horse but cannot fly. The kiwi is a nocturnal bird and uses its long beak to collect worms and insects.



Flying birds. They form the majority of the modern birds and are found practically all over the world. They show many interesting adaptations The smallest flying birds are the humming birds, no bigger than your thumb The largest flying birds are some eagles

Fig. 27.6. The penguin. This flightless bird has swimming paddles in place of wings. Most penguins do not build nests but ←incubate their eggs in a fold of skin between their feet. After J. Fisher, J. Huxley, G Barry and J. Bronowski, *Nature*, Rathbone Books Limited, London, 1960

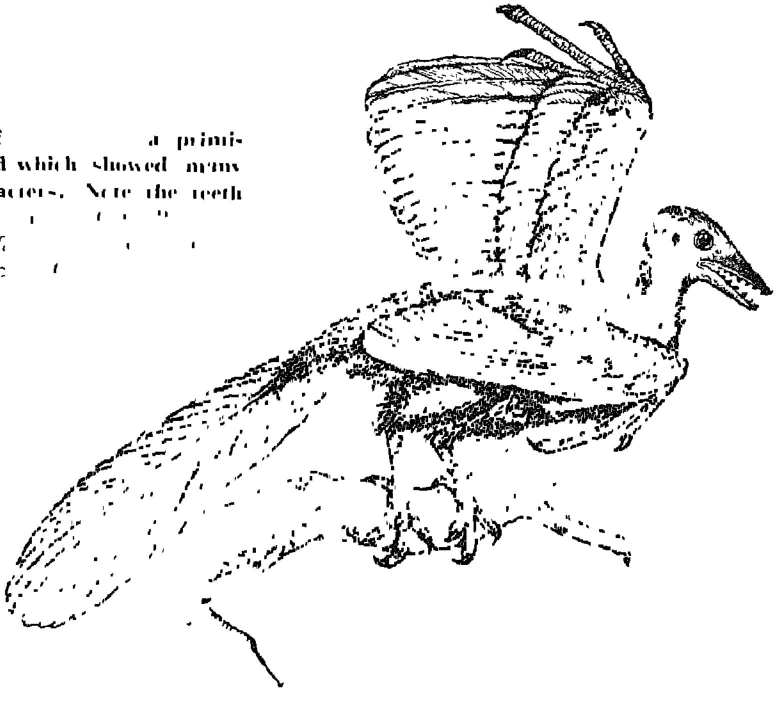


Fig. 27.7. Restoration of [illegible] **a primitive fossil bird which showed many reptilian characters. Note the teeth in the beak.** [illegible]
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Archaeopteryx, a strange fossil bird. You would learn in Section VI that many animals which existed in the past have left their remains (fossils) in the rocks. A strange fossil bird of this type (Fig 27.7) was discovered in Germany. It existed about 150 million years back and can be considered a link between the reptiles and the birds. It had teeth in the jaws, fingers and claws in the wings, and a long tail with an extending vertebral column. These are reptilian characters and are not seen in the modern birds.

Fig. 27.8. The peacock in a dancing pose. Because of its beauty and long association with our culture, the peacock has been recognized as the National Bird of India. Courtesy of the Delhi Zoological Park.

Bird Behaviour

Courtship in birds, their nesting habits and social behaviour are very interesting. Their beautiful colours and shapes incidentally serve for sexual attraction. Some birds like the male peacock (Fig. 27.8) make dancing gestures to attract the females. Their songs and calls have varied purposes (sexual attraction, mutual recognition, or frightening the enemy). Most birds make nests. Those made by the weaver bird, the tailor bird, and many others are very nicely composed (Fig 27.9). Indeed, birds are fine 'craftsmen', and also take great care in rearing their young ones.

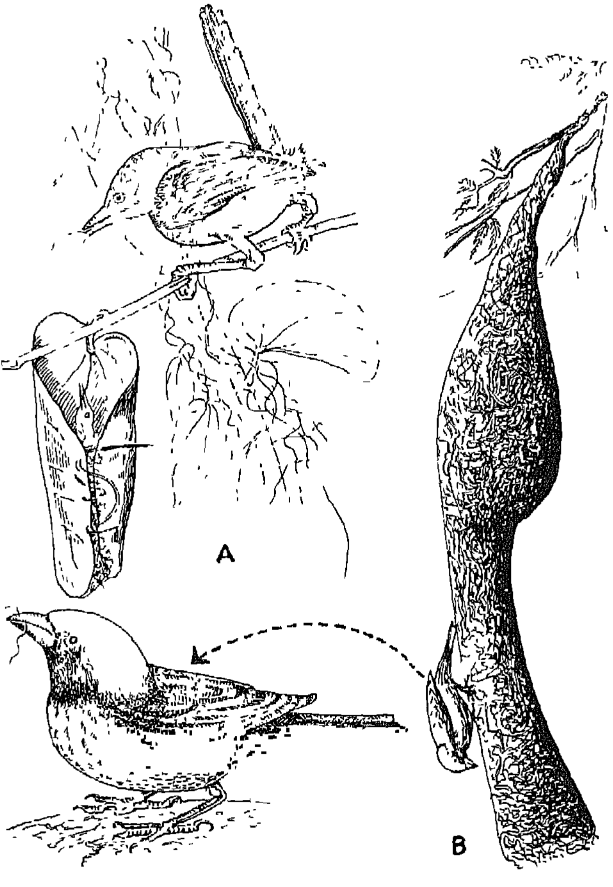

Fig. 279. A. The tailor bird with its nest made of a rolled-up leaf. The bird stitches the edges of the leaf with threads of wool or cotton by means of its pointed beak. B. Bottle-shaped nest of the weaver bird, 'baya'. These nests are woven out of grasses and paddy straw, and are commonly seen hanging on the trees.

Many birds live in groups, i.e. they are social. You must have seen groups of pigeons, crows, ducks, and of many others. Their distinct calls and plumage help them in mutual recognition.

Migratory habits. In your locality you find many birds such as sparrows, crows, kites and pigeons throughout the year. These are called the local or resident birds. But there are others which appear only in a particular season. The wagtails, certain ducks, rosy pastor and many others come to the plains of our country only in the winter. These are the migratory birds (Fig. 27.10). Their true homes are far away in the Himalayas or even further north. They leave their homes before the winter sets in, stay in different parts of India during the winter, and go back with the onset of the summer. This to and fro movement goes on year after year and is called **bird migration.** Migratory birds are found in practically all the countries.

Bird migration is usually studied by a method called ringing or **banding.** At various places in the world, scientists trap

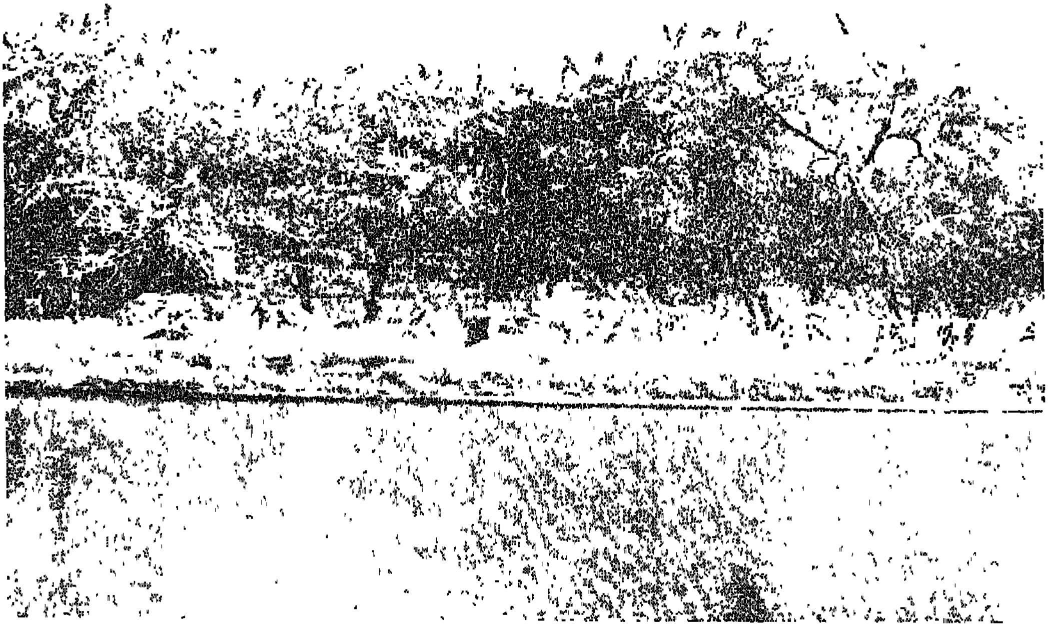

Fig. 27.10. A large group of painted storks photographed in the Delhi Zoological Park in the month of December. These birds migrate every winter from across the Himalayas to Indian plains.

the birds and tie around their feet aluminium rings (Fig. 27.11) which bear the date and the name of the place where the bird is ringed. Similar record is kept in a register and the banded birds are set free again. After some time these birds may be sighted or caught at some other place. By this method people can learn about the routes and destinations of the migratory birds.

Birds migrate mainly to avoid shorter days in very cold regions where the food also becomes scarce in winter. On returning in spring they find their original homes quite suitable. This seasonal journey of the migratory birds is a natural instinct. The setting out on the journey is controlled by certain hormones whose production is again governed by the duration of daylight. The most interesting migratory bird is the arctic tern which flies from its natural home in the arctic region to the other end of the earth in the antarctic region, a distance of about 1,76,000 km, and the same distance back home every year.

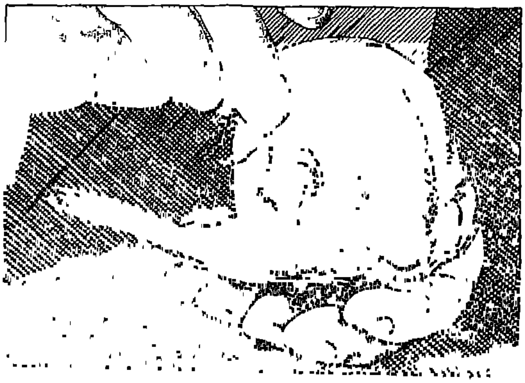

Fig. 27.11. Studying bird migration. An inscribed aluminium band is put round the leg of a migratory bird which is then released to go its way. By spotting the banded bird in other places its path and destination of migration are noted. After T J Moon, J H Otto and A Towle, *Modern Biology*, Holt, Rinehart & Winston, Inc., New York, 1960.

Birds in Relation to Man

There are many birds such as sparrows, parrots and crows which destroy our crops. Hawks and owls kill some of the wild and domestic birds. Some birds are believed to transmit certain diseases to man and cattle. However, a few birds are very useful in many ways. You enjoy looking at beautiful birds and hearing their sweet songs. The quails, partridges, cranes, bulbuls, mynas and peacocks are delightful pets. Many birds are doing us great service by killing harmful insects, rats, and other enemies of our crops. The crows, kites and vultures are efficient scavengers in consuming and cleaning the remains of dead animals. Certain birds like the purple sunbird pollinate the flowers, and some others disperse the seeds. The ducks, fowl and many other birds provide us with eggs and flesh for food. The feathers of certain birds are used for decoration and for stuffing cushions, etc.

Common Indian Birds

Bird watching is a very absorbing hobby. In most localities you will be able to spot out more than thirty different types of birds. Some of these are shown in figure 27.12. The 'baya' or weaver bird is famous for its skill in weaving bottle-shaped nests. The tailor bird stitches the edges of a pair

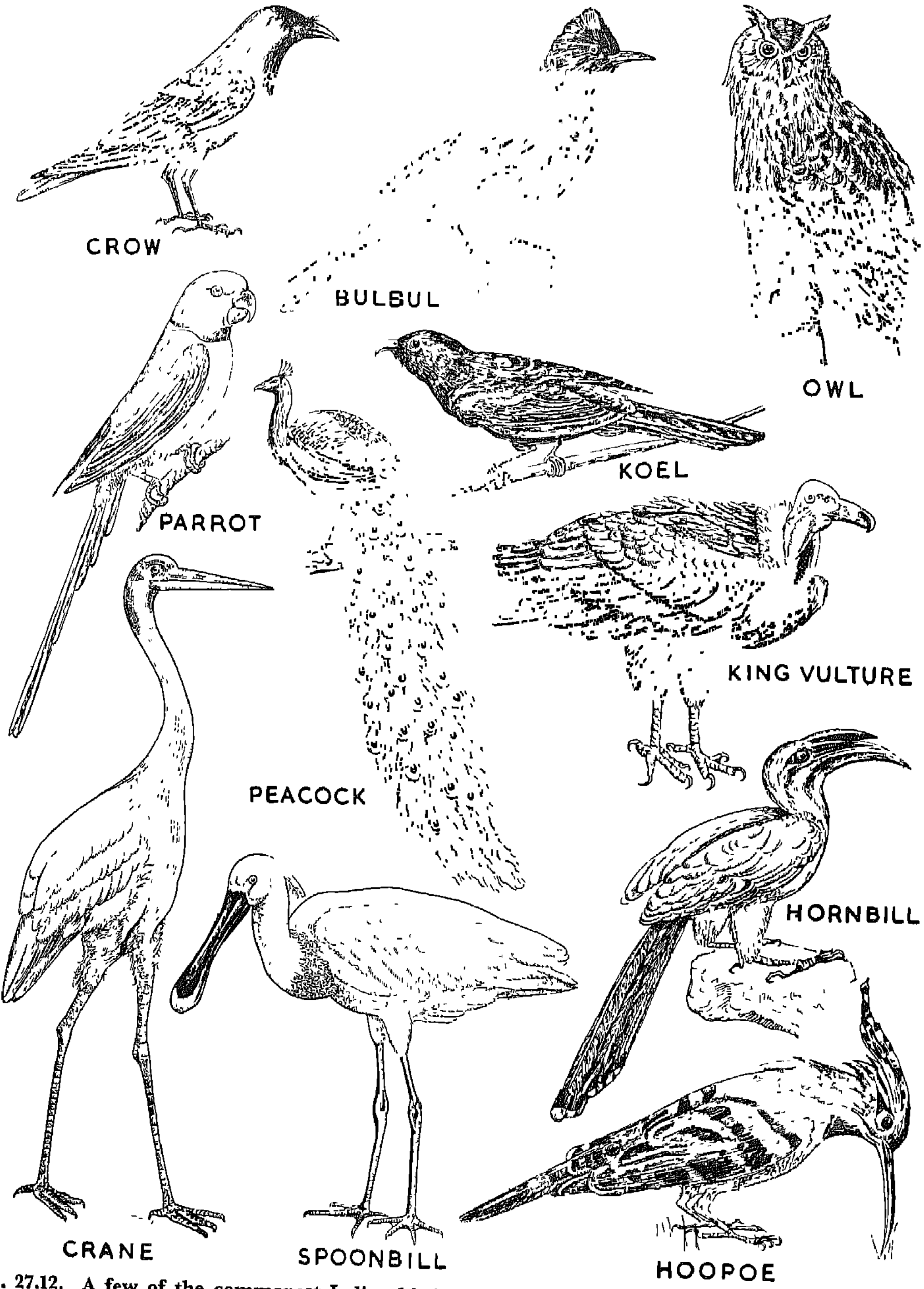

Fig. 27.12. A few of the commonest Indian birds. After Salim Ali, *The Book of Indian Birds*, Bombay Natural History Society, Bombay, 1964.

of leaves to lay eggs inside You can find it in most bushes and creepers. The bulbuls are of many kinds, the commonest being the red-vented bulbul having a crest of feathers on the head and a bright red spot under the root of the tail The 'koel' is known to all owing to the sweet song of the male in the spring. The bank of a lake, river, or canal will usually show many lovely birds like the crane, heron, king fisher, etc The vultures, eagles and kites are some of the largest birds. Hoopoes, mynas, seven sisters, and crows are daily visitors of our houses. The house sparrow even makes its nests in our houses.

SUMMARY

Birds are vertebrates with feathers and wings They have beaks but no teeth. They have claws in their toes. Their body is well adapted for flight. Some birds are flightless. Singing, nest-building, and migration are some of the interesting aspects of bird behaviour. Some birds are injurious to mankind but others are useful in many ways

QUESTIONS

1. Name at least two birds which do not fly.
2. Name some birds which visit India only during winter
3. Which is the bird that undertakes the longest migratory journey?
4. Describe the usefulness of birds to mankind
5. How does a humming bird hum?
6. Name a few birds of your locality and mention the part of the year in which they are more abundant
7. Are the hen's eggs, as sold in the market, fertilized or unfertilized?
8. A bird's egg must be fertilized internally. Explain.
9. How does a developing chick breathe inside the shell?
10. Hens are sometimes given powdered mollusc shells or small stones in addition to the usual feed. Explain why this is necessary.
11. Explain why the bird's heart usually beats faster than that of any other animal.

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CHAPTER 28

Mammals— The Hairy Vertebrates

THE mammals (Gk *mamma* = breast) are some of our most familiar animals in which the females suckle their young ones Man also belongs to the same class. Our association with other mammals is quite ancient and intimate. They give us food and clothing They work for us in the fields, carry our loads and even ourselves for long distances However, some mammals such as rats and rabbits constantly rob us of our food Some others are beasts of prey and quite a few are harmful to us and to our domesticated animals.

Mammals are found in every part of the world—from the poles to the equator, from the snow-covered mountains to the hot deserts, in lakes, rivers and in deep oceans, in thick forests as well as in barren places, in the air and in the dark caves This means that mammals have an extraordinary power of adaptation They vary in size from the tiny shrews to the gigantic whales

General Characters

All mammals share certain common features They have a hairy skin and outwardly projecting external ears They do not lay eggs but give birth to young ones, the only exceptions being two members from Australia (Figs. 28.1 and 28 2). In all cases the young ones are nourished on their mother's milk The milk glands (**mammary glands**) are specialized skin glands opening on the teats The skin also contains sweat glands opening by pores on the surface The teeth are set in sockets and grow in two sets, the milk teeth and permanent teeth. They are differently shaped for biting, tearing and grinding. All mammals have a muscular diaphragm separating the chest cavity from the abdomen. The brain, especially the cerebrum, is highly developed and mammals are, therefore, the most intelligent of all animals Whether the neck is small as in a rat or long as in a giraffe, it is always composed of seven neck vertebrae. All mammals have non-nucleated red blood cells, and maintain a constant body temperature They are, therefore, said to be **warm-blooded** animals Except in the egg-laying mammals in which the urinogenital aperture

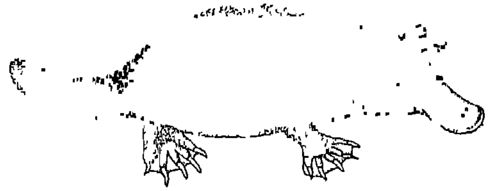


Fig. 28.1. The duckbill, a primitive egg-laying mammal of Australia. It swims about in streams with its webbed feet. After J. Fisher, J Huxley, G. Barry and J. Bronowski, *Nature*, Rathbone Books Limited, London, 1960.

and the anus are combined, these are, as a rule, separate openings, and there is no cloaca. This is clearly an advancement over all other vertebrates in which a cloaca is present. Except in a few instances like the bats the testes are lodged in scrotal sacs outside the abdomen

General Survey of Mammals

Biologists divide mammals into nearly fifteen groups. We shall deal here with the more important of these.

The egg-laying mammals (Monotremata). To this group belong two strange and primitive forms from Australia—the duckbill (Fig. 28.1) and the spiny ant-eater (Fig. 28 2). They have a hairy skin but no external ear or **pinna.** The hairs are modified into spines in the spiny ant-eater. There is a common anal and urinogenital opening, and in the male the testes remain in the abdomen They do not give birth to young ones but lay eggs and incubate them The mother has no teats and the milk simply trickles along the hair.

The pouched mammals (Marsupialia). As the name indicates, the females of this group possess a pouch or a fold of skin for carrying the young ones The most well-known marsupial is the kangaroo (Fig. 28.3). It is very common in Australia, but you can also see it in most of the zoos. The eggs are incubated within the mother's womb but the young ones are born very small, only about 3 cm long The mother gently places them in a pouch (**marsupium**) formed by a fold of skin on the lower part of the body. Each young one attaches itself to the opening of a milk gland and thus keeps feeding. In about four months it grows to a stage when it can come out of the mother's pouch The opossums of South America and the phalangers and koala bears of Australia are also pouched mammals They all possess projecting external ears. Even the pouched mammals are primitive since they have no adequate arrangement to nourish the young one while it is developing inside the mother's womb.

In many ways the above two groups are not typical. In the true mammals

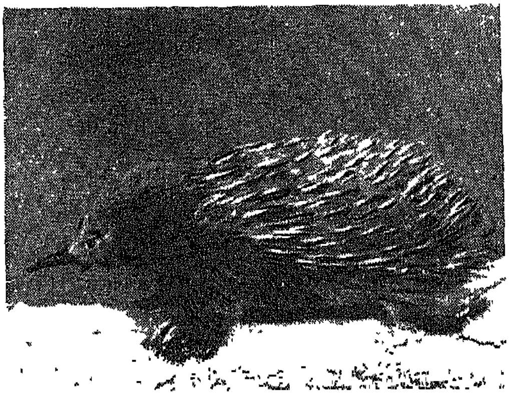


Fig. 28.2. The spiny ant-eater, another egg-laying mammal of Australia. Its body is protected by sharp spines but it also has true hairs. Note the slender snout and sharp, nailed feet which are used for digging the soil,

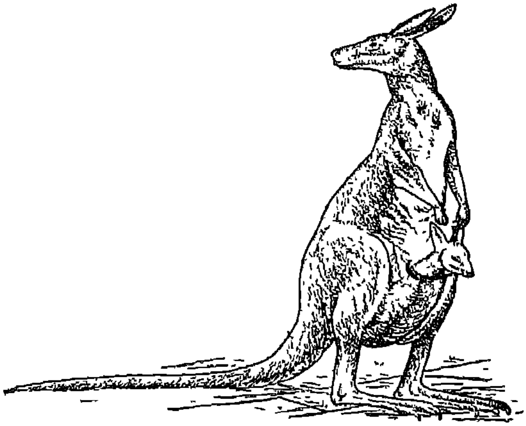


Fig. 28.3. The kangaroo, a pouch-bearing animal of Australia. It has short fore-limbs but long and powerful hind-limbs which it uses for jumping. The young ones are reared in a pouch in the belly of the mother.

(**Eutheria**), described below, the young ones stay longer in the mother's womb where they are nourished through a special outgrowth, the **placenta.** Therefore, these are also called **placental mammals.**

The insect-eating mammals (Insectivora). Moles, shrews and hedge-hogs come under this group (Fig 28 4) These look like rats and mice, but there are certain important differences For example, the canine teeth are always present in the insectivorous mammals, but never in the rats. Mostly they dig burrows in the ground. The eyes are very minute and often hidden in the fur, in moles and shrews they serve only to distinguish between light and darkness. The moles are subterranean, they have powerful fore-limbs with which they dig the ground. In the hedge-hog, which is quite common throughout the Old World, the skin is covered with short pointed spines All these mammals feed primarily on insects and other small invertebrates such as earthworms and spiders. Insectivores were the earliest placental mammals.

The toothless mammals (Edentata). The armadillo and the scaly ant-eater (Fig. 28 5) fall under this group since they have no teeth in front. A good many forms live in America. The scaly ant-eater or pangolin is quite common in India. Its body is covered with large, overlapping horny scales with a few hairs between them. The head is small and pointed, and the brain is poorly developed A long sticky tongue helps in catching ants and termites (white ants). The South American armadillo is a distant relative of the Indian pangolin.

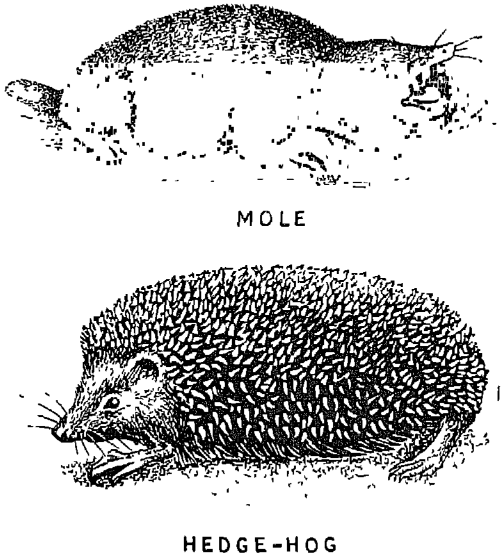


Fig. 28.4. Two small insect-eating mammals. The mole has a fur but the hedge-hog bears small spines on its skin. After J Z Young, *The Life of Vertebrates*, Clarendon Press, London, 1950.

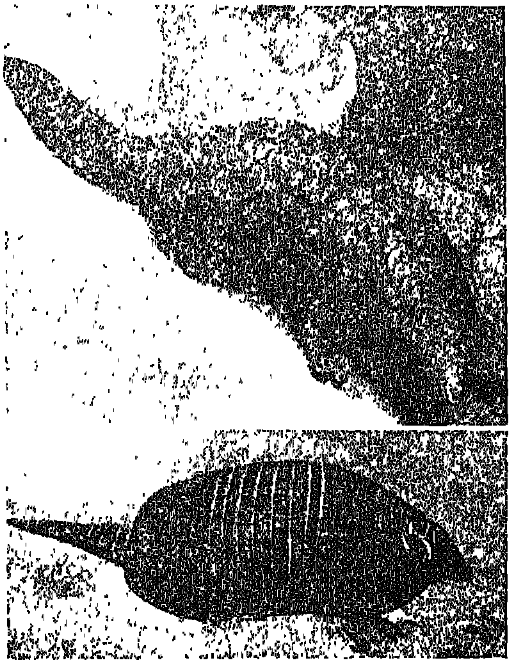


Fig. 28.5. Two toothless mammals. The body of the pangolin or scaly ant-eater is covered with plate-like scales. The animal is active during the night and feeds mainly on ants and termites. The armadillo has an armour of bony plates. It has the unique ability of rolling itself into a ball to frighten the enemy.

It has a heavy armour of bony plates on its body, and often produces four young ones from a single egg. This is because the four cells resulting from the first two divisions of the fertilized egg become separated and each one produces a baby. This process is comparable to the production of identical twins in man.

The gnawing mammals (Rodentia). Hares, rabbits, rats, mice, squirrels and porcupines are common examples of this group (Fig. 28.6). They all have strong chisel-like front teeth (incisors) which are used for biting. These teeth are self-sharpened by regular use. The rodents feed on vegetables and grains, and lack canine teeth.

The rabbits live in groups in underground burrows but can be tamed. Their young ones are naked (without hair) and blind at birth. The hares live singly in bushes or grass, their young ones are hairy, and have functional eyes from the very beginning. They are not easily tamed. The porcupine

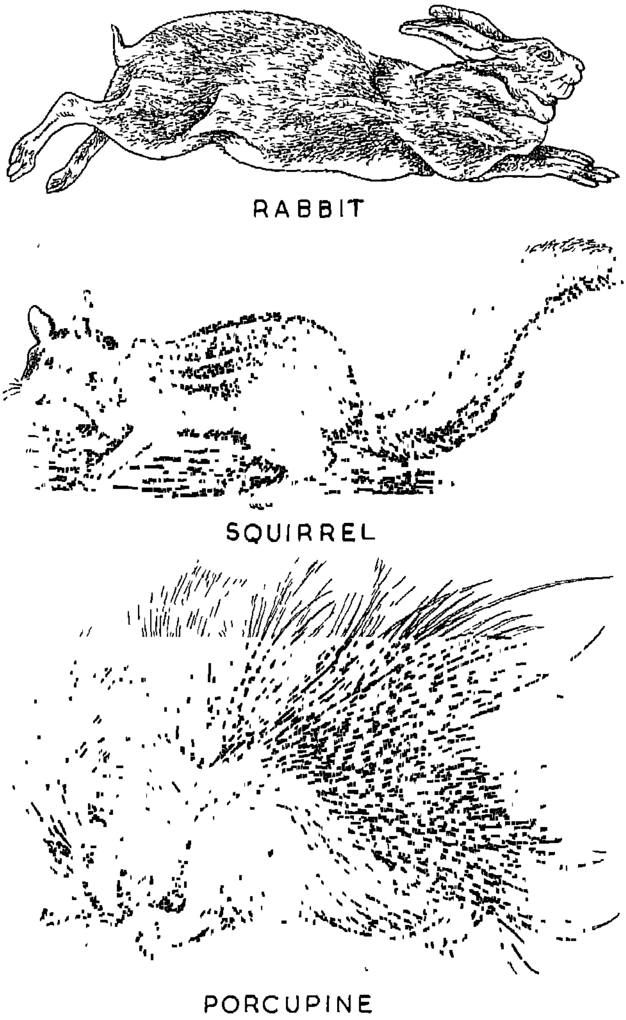


Fig. 28.6. Three of the common rodents. The porcupine is a peculiar-looking mammal with powerful quills or spines which may be driven deep into its enemy's flesh. When frightened, the animal assumes the shape of a ball covered with spines. From various sources.

is common in India and some other countries Its body is covered with long powerful spines which serve to defend it from the enemy It feeds on cereal crops. The rats and mice are highly destructive to crops and stored food. The rat is also a carrier of bubonic plague. However, rats, rabbits and guinea pigs are very good objects for experimentation in biological and medical research.

The hoofed mammals (Ungulata). Horses, cows, buffaloes, sheep, camels, deer and other animals with hoofs form a distinct group. Their hoofs are modified claws or nails The legs are suited for running and have lost the power to grasp. They live mostly on land but some, like the hippopotamus, live in the rivers.

The hoofed mammals (Fig 28 7) are divided into two categories—those having an odd number of toes (one or three), and those with an even number (two or four) The horses and asses, with one toe in each foot, are the commonest examples of odd-toed hoofed mammals. The African zebra is also a type of horse with only one toe in each foot The Indian rhinoceros has three toes in each foot. On its nose it bears a single horn This is not a true horn or bone but a compact bundle of hairs glued together Its skin is thick and strong, and is thrown into many folds In olden days people used to make shields out of rhino's skin. A different rhino with two horns on its nose is found in Africa and South East Asia. The tapirs are strange-looking animals having a long protruding nose. They are found in South America and South East Asia. They have three toes in the hind-legs but four in the front legs The fourth toe is, however, very small

In the even-toed hoofed mammals such as the ox, sheep, camel, giraffe (Fig. 28 7) and deer (Fig. 28.8), there are two toes (third and fourth) in each foot The other two toes (second and fifth) are sometimes represented as two small vestiges hanging behind the hoofs, as in buffalo The first toe has completely disappeared These mammals have no upper front teeth Most of them chew the cud and are called **ruminants.** Their stomach is very characteristic and has four chambers (Fig. 28 9) The food first enters a large paunch or **rumen.** Later, small lumps of this food are taken back into the mouth for a very thorough chewing (cud-chewing) The chewed food is then swallowed again. and this time it enters the subsequent chambers of the stomach where it begins to be digested

The camel is truly the 'ship of the desert'. Can you make out the important characteristics which make this animal suited for life in desert? It can live without drinking water for ten to fifteen days This is due partly to the special structure of its stomach The first and the last chambers of the stomach have numerous little hollow protuberances. When the camel drinks water, the latter fills into the protuberances which then become sealed by a circular muscle. When necessary, the chambers open and allow the water to flow into the stomach little by little At present, there are only two living species of camels both of which are fully domesticated. The Indian camel (Fig. 28 10), which is one-humped, is also found in parts of South East Asia, Arabian region and North Africa. The Bactrian or Central Asian camel is smaller and more hairy, it bears two prominent humps (Fig 28 7).

The African giraffe is a tall, camel-like mammal with a beautiful skin Its long straight neck supports the head high up for browsing on the trees The hippopotamus, also found in Africa, is a massive creature with very powerful jaws. It lives most of the time in water.

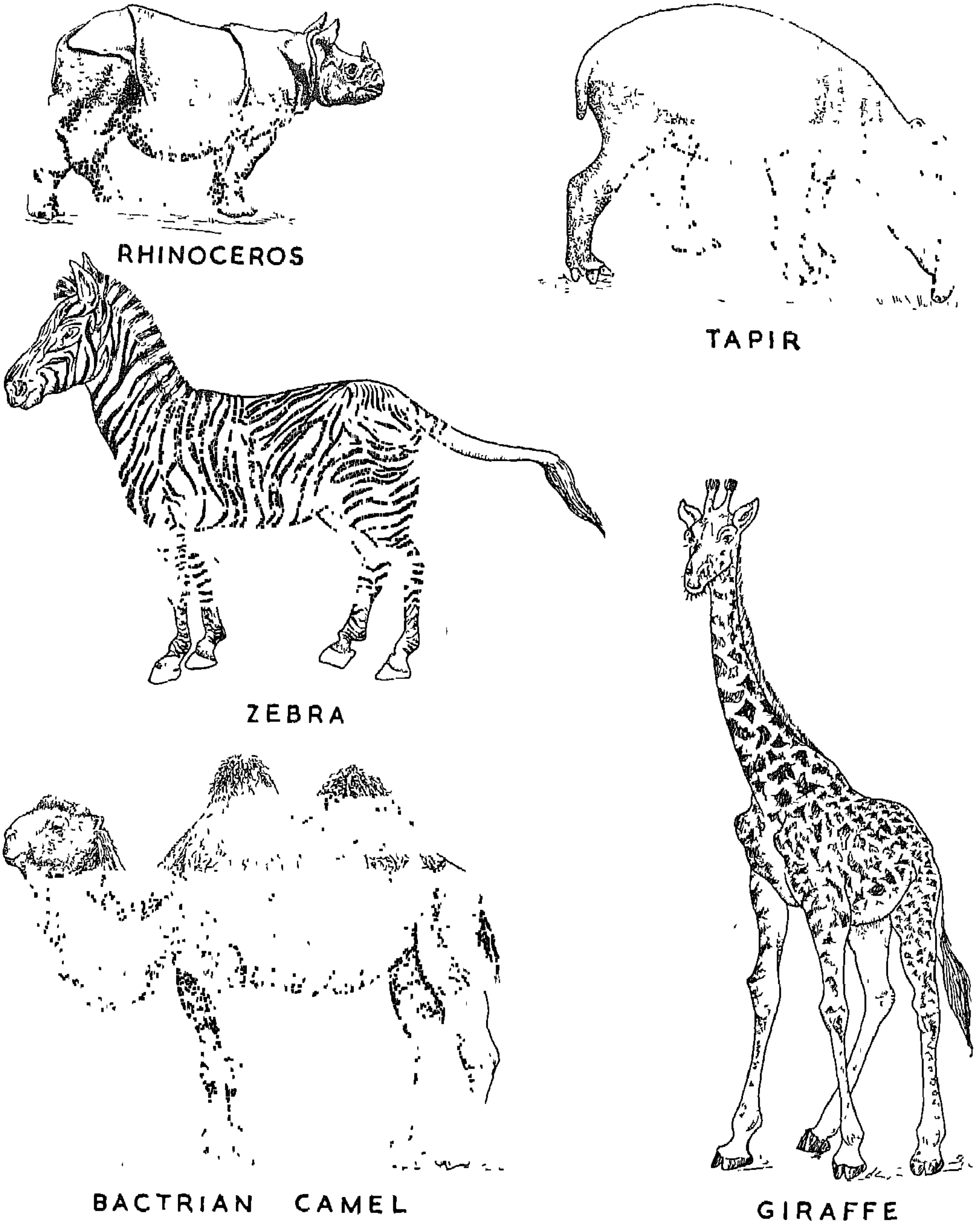


Fig. 28.7. The hoofed mammals. The rhinoceros is a huge, thick-skinned animal, easily recognized by the horn-like projection on the nose. It is found in parts of Bengal and Assam. The tapir is a nocturnal animal with a long protruding snout. The zebra is a fast moving, beautifully striped animal of the horse family. It is found wild in parts of Africa. The giraffe is an elegantly spotted, African mammal that may be as much as six metres tall. Although somewhat resembling a horse, it is actually a cud-chewing animal like the cow. The Bactrian or two-humped camel is an important beast of burden in certain desert parts of Central Asia. From various sources.

Most ruminants possess **horns.** These are useful for their defence. The horns of cattle and sheep are hollow and are made of a material similar to that of our nails. The solid horns of the deers are called **antlers** and are made of bone. The antlers are shed and regrown every year. The small horns of the giraffe are also bony but these remain covered by the skin and are never replaced.

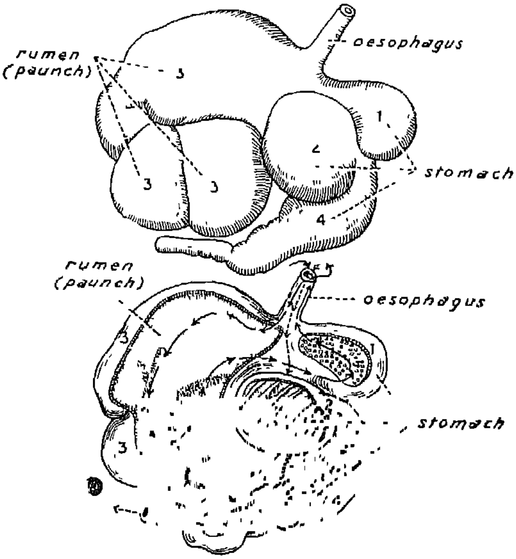


Fig. 28.9. The stomach of a ruminant. The arrows indicate the path along which the food moves. After T.I. Storer and R.L. Usinger, *General Zoology*, McGraw-Hill Book Company, Inc., New York, 1957.

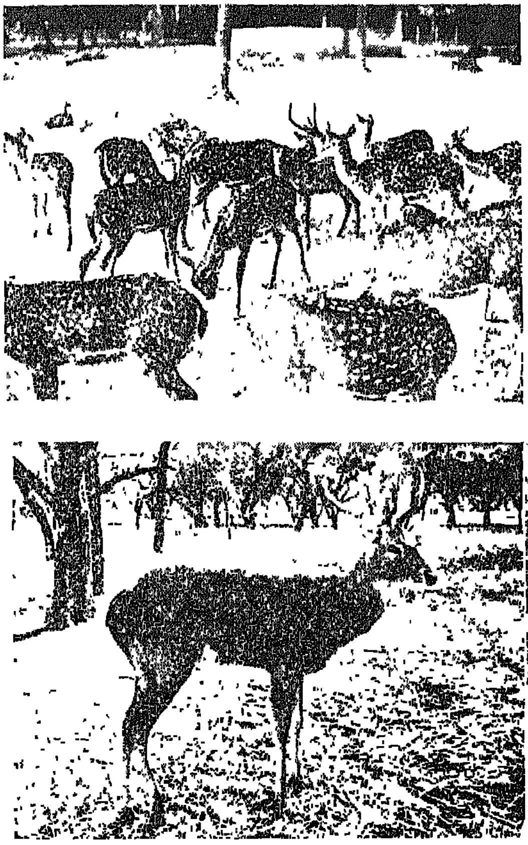


Fig. 28.8. The deers are favourite game animals whose flesh is valued as food. Only the males carry the antlers. The spotted deer or 'chital' is found only in South India and Ceylon. The swamp deer or 'barasingha' is found in Madhya Pradesh and Assam. Courtesy of H.Y. Mohan Ram, Department of Botany, University of Delhi

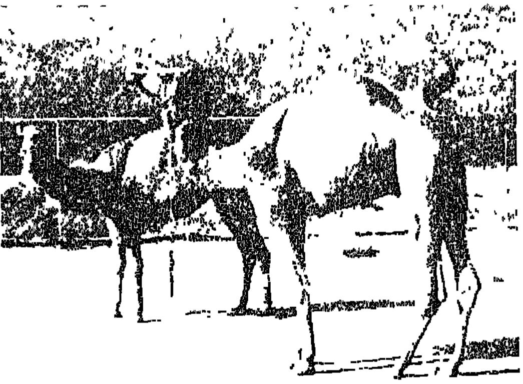


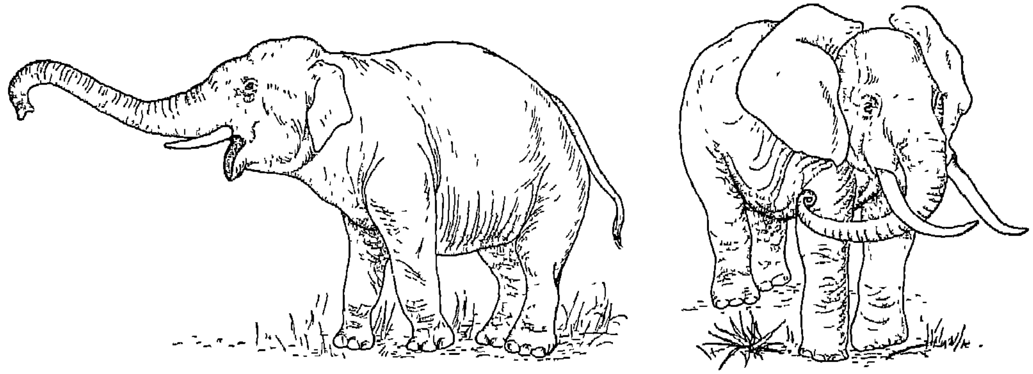
Fig. 28.10. Owing to the presence of padded feet, slit-like nostrils (which can be closed tightly during dust storms) and water pockets in the stomach, the one-humped or Arabian camel is well-adapted for life in the arid regions.

The pigs and boars have a mobile snout bearing the nostrils. While most hoofed mammals feed on plants, the pigs and boars eat both animal and plant material. The canine teeth are more powerful in the males.

The mammals with trunks (Proboscidea). This group includes the elephants (Fig. 28.11). These are the largest of the present day land animals. Their trunk (proboscis) is a specialized snout. The **tusks** which give the valuable ivory, are the modified upper incisors. There are only two living species of elephants—the Asiatic and the African. The latter has a slopy forehead and much larger ears. The Asiatic species has only one finger-like appendage at the tip of the trunk while the African species has two. Many types of fossil elephants have been discovered from different parts of the world including the Himalayan region.

The flying mammals (Chiroptera). The true flying mammals are the bats (Fig. 28.12). The flying squirrels, which can only glide with lateral skin folds, constitute a separate group. In the 'wings' of the bats the flying membrane is a sheet of skin supported by long digits of the limbs. The small thumb is free and clawed, and is used as a grasping organ. The bats have distinct external ears, and teeth set in sockets. The testes remain in the abdomen. Bats are active during the night. Even in total darkness they fly with great accuracy, without colliding against walls or other obstacles. Their eyes are very poorly developed, but they make use of a 'radar mechanism'. The flying bat produces a series of shrill cries which are inaudible to the human ear. These have a frequency of about 50,000 vibrations per second. The human ear can hear waves of up to 20,000 vibrations per second. The vibrations produced by the bat are reflected back as echoes from nearby objects. The bat is able to avoid collisions by noting these echoes. Some bats eat fruits while others feed on insects. The vampire bat of South America even sucks blood from cattle and man.

The flesh-eating mammals (Carnivora). The lion, tiger, bear, dog and cat come under this group. They have strong limbs with powerful claws. The canine



INDIAN ELEPHANT AFRICAN ELEPHANT

Fig. 28.11. The tusks of the elephants are actually the enlarged incisors and are more prominent in the male. The Indian elephant inhabits the dense forests of the lower Himalayas and Nilgiris, Western Ghats, Mysore and Coorg. It is captured and trained for use as a beast of burden in forest areas, hills and valleys. The adult animals are almost hairless. In spite of their huge size, the elephants are remarkably good swimmers.

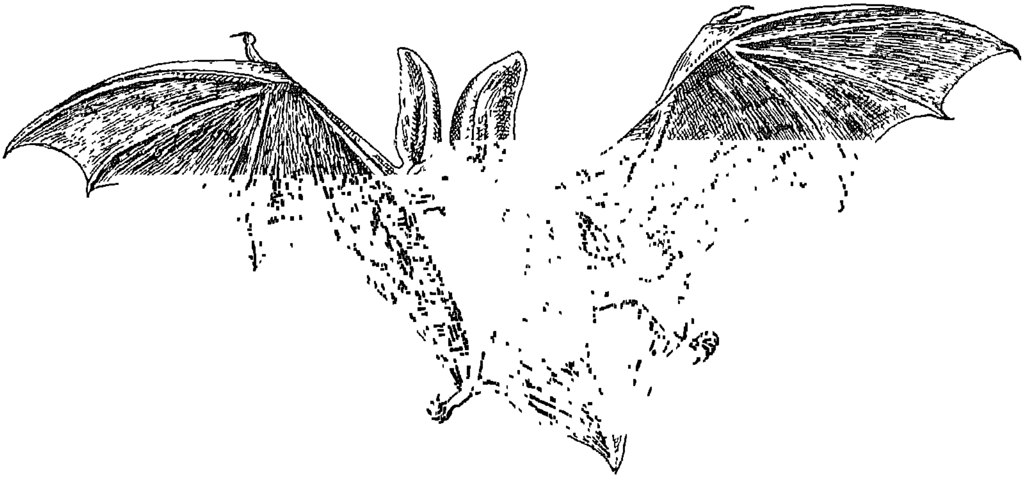


Fig. 28.12. The bat, a flying mammal. All the four-limbs support the membranous fold of skin.

teeth, which are strong and often projecting, are used for tearing the flesh of the prey Among the land carnivores are the dog, fox, jackal, hyena, lion, tiger, panther and bear (Fig 28 13) The true aquatic carnivores are the marine seals and walruses. These are caught for their beautiful fur The otters may be found in freshwater as well as in sea, but they have a greater resemblance to the land carnivores

✓**The whales (Cetacea).** The whales, dolphins and porpoises are examples of this group All these are completely adapted for life in water The body has a fish-like appearance and the front limbs have become swimming paddles The hind-limbs are totally absent There are no external ears and the hairs are found only in the embryos. They have under the skin a thick layer of fat (blubber) which protects them from intense cold. The whales and dolphins are found mostly in the cold seas. From very ancient times people have been catching the whales for flesh, bone and oil. The oil was once used for burning in lamps. The blue whale is nearly 30 metres long and is the largest of all known animals (Fig 28.14) Whales feed on fish and other sea animals, both large and microscopic The porpoises are fresh-water forms. One of these is found in the lower parts of the Ganga

The mammals with superior brains (Primates). Here belong the monkeys, lemurs, apes and man The chief characteristic of this group is the possession of hands with which the animals can grasp objects. The thumb is somewhat free from the rest of the fingers and can be apposed to them in order to hold and manipulate things with ease The feet of the primates, excluding only man, are also of a grasping type. This grasping power has enabled the primates to lead an arboreal life, climbing from branch to branch or swinging from the twigs of trees. Most primates can stand erect and can walk on land on their two feet Instead of the claws there are nails in the fingers and toes. Their eyes are placed more towards the front This arrangement gives them a better judgement of distance and a depth of vision. Practically all the primates have two teats on the

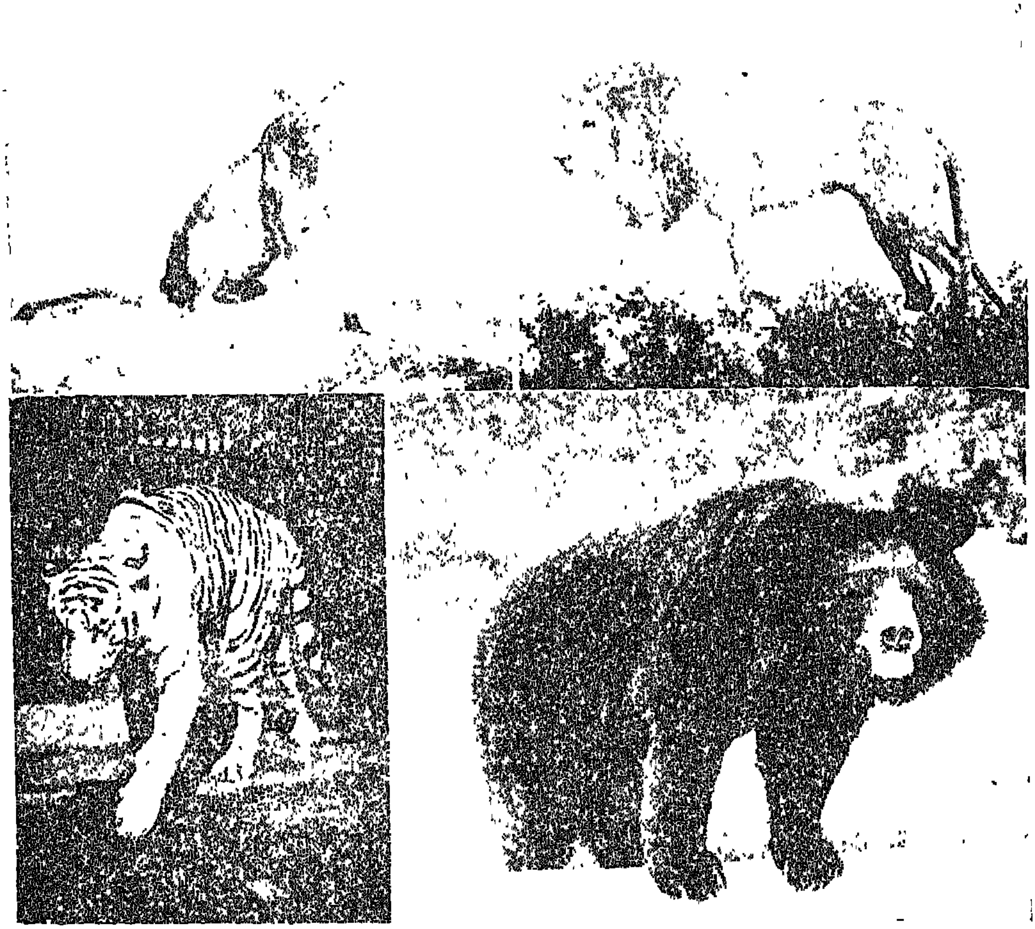


Fig. 28.13. **The lions of the Gir forest of Gujarat have a uniform brown colour and a tufted tail. The male with its shaggy mane is far more handsome than its mate. The tiger has a beautiful brown body with black stripes. The male is much larger than the female and may reach a length of three metres. The bear has long coarse hairs and hooked claws. It is sometimes tamed to play amusing tricks.**

breast. The brain is more highly developed than that of all other animals. Although the primates are not physically superior to other animals, they are successful due to their superior nervous system and efficient hands.

The New World or American monkeys have a flat nose and a grasping (prehensile) tail and lack cheek pouches. The Old World monkeys have non-grasping tails and cheek pouches. Our common monkey (Fig. 28.15) is the rhesus. It is a major pest of gardens and fields. It is exported in large numbers to experimental laboratories all over the world. The langur (Fig. 28.16) is another type of monkey with a black face and a long tail.

There are only four man-like 'great apes' living at present—the gibbon, orang-utan,

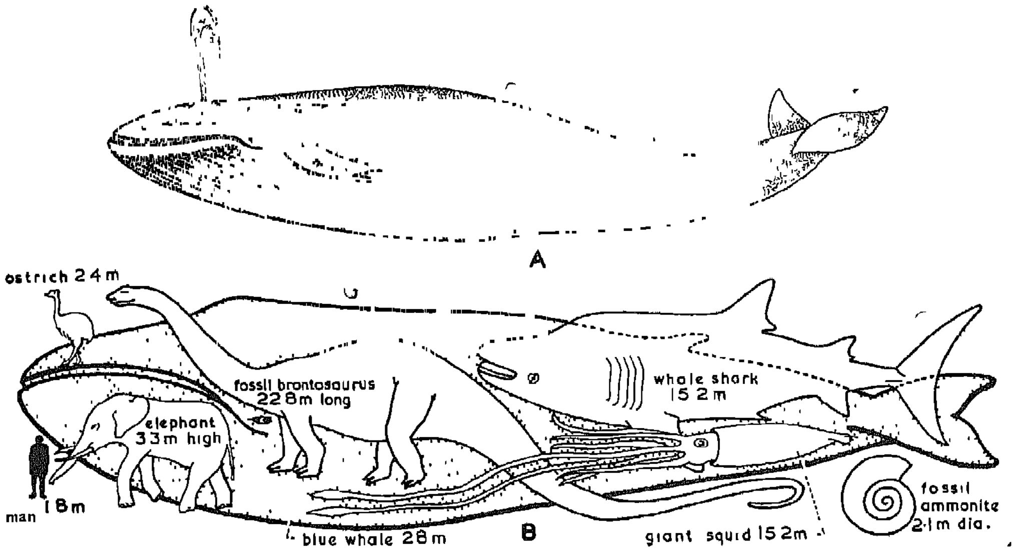


Fig. 28.14. **A. The blue whale, the largest known living mammal. This fish-like mammal completely lacks hairs and hind-limbs. The nostrils are situated at the top of the head. The figure shows a phenomenon called spouting or the exhalation of air. On reaching the surface, the hot and humid exhaled air suddenly condenses and this results in a spray-like appearance. B. The sizes of various animals in comparison to the blue whale.** Adapted from T I Storer and R.L. Usinger, *General Zoology*, McGraw-Hill Book Company, Inc , New York, 1957

Fig. 28.15. **The rhesus monkeys are common around tanks and places of pilgrimage in India. They have proved very useful in medical research, especially that concerned with polio virus.** Courtesy of the U S Information Service, New Delhi

Fig. 28.16. The langur, another Old World monkey widely distributed in India. It is notorious for robbing eatables and damaging house-hold things.

Fig. 28.17. The gibbon or hoolock, the smallest of man-like apes. It is found in India only in the forests of Assam. With its long arms it can move swiftly along the branches of the trees (overarm swinging).

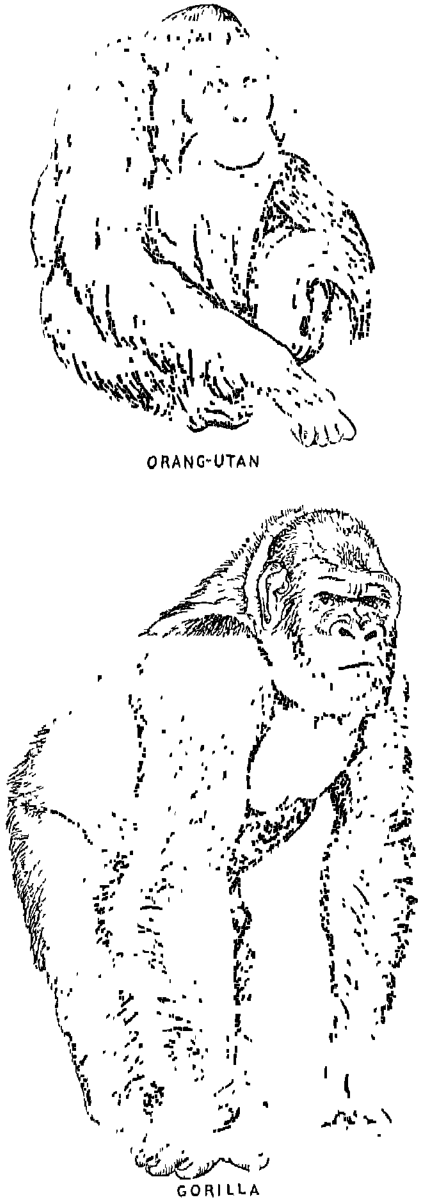


Fig .28.18. The bigger, manlike apes. The orang-utan, also called the 'man of the woods', lives almost entirely among the leafy branches in Borneo and Sumatra. Despite its bulk it swings with great agility from one tree to another. The gorilla is the tallest and most fierce looking ape found in Africa.

gorilla, and chimpanzee (Figs. 28 17 to 28.19). They walk erect and have long arms with which they swing on the trees They have no tails. The gibbon is the smallest of the great apes, less than half the size of man. Its arms are proportionately the longest, almost reaching the ground It is found in South East Asia, including India The orang-utan has longer arms and reddish hair, and is confined to Borneo and Sumatra The gorilla is found in several parts of Africa. It is taller than man, and may weigh as much as 250 kg. Unlike the other apes, it dwells on the ground The chimpanzee is also found in Africa, and is smaller than the gorilla. It is a very intelligent animal, and can be trained to do many jobs almost like a man

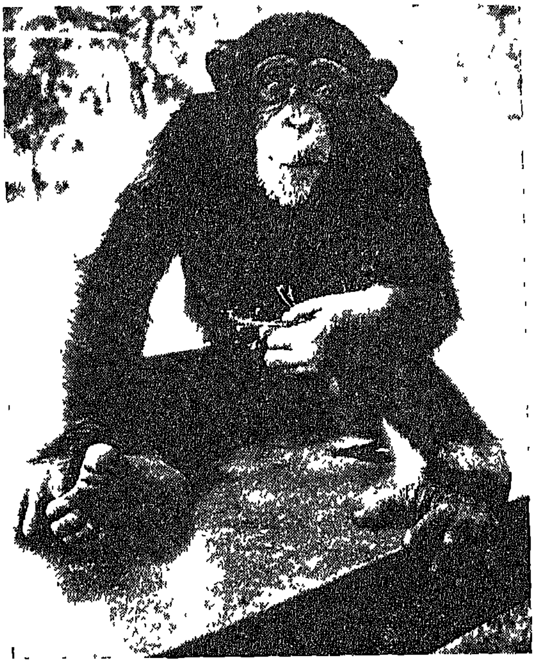


Fig. 28.19. The chimpanzee, an intelligent and comical ape of Africa. Though its hands resemble those of man, they lack the manipulative power, especially of the thumbs.

Man, the Superior Mammal

All living human beings belong to a single species, *Homo sapiens* (Gk. *homo*=man; *sapere*=to be wise). It is true that the different races of mankind, such as the caucasoid, mongoloid, negroid and australoid differ from each other in numerous details of body-build, hair, face, etc., yet they are all capable of fertile inter-racial marriages This is the chief reason for including all human races in a single species

Man is clearly a mammal. His nearest relatives in the modern biological world are the great apes (gorilla, chimpanzee, orang-utan and gibbon). Many species of man, some very similar to us and others sufficiently different, lived in the past ages Man and the great apes have several similarities such as the absence of a tail and cheek pouches These lead us to believe that both evolved from the monkey-like animals Later, even these two groups diverged from each other into the tree-dwellers with a semi-erect posture and longer fore-arms for swinging (the great apes), and the ground-dwellers with an erect posture and larger brains (man) Of the numerous important tendencies in human evolution were the formation of a flat and more vertical face, reduced brow ridges, less protruding lower jaw, a distinct chin, larger brain, manipulating hands, thinning of the body hair and continuously growing scalp Even more important than these physical changes was the development of the behavioural and cultural characteristics. Man has been evolving as a social creature with a high intelligence, capacity to learn, ability to express in languages, and to work with hands and tools All these characteristics have enabled him to evolve an ever-progressing civilized society He is continuously gaining a mastery over his surroundings.

Man dominates the earth. The earliest and longest cultural stage of man was the Stone Age in which he used flint tools This age prevailed between 800,000 and 6,000 B C The Stone Age man was an integral part of the biological community, living almost entirely on hunting His number was strictly limited by the availability of the prey. It has been estimated that the population of Stone Age man was around ten million.

Towards the close of the Stone Age came a great cultural revolution, namely, the development of agriculture and domestication of animals This advancement changed the pattern of life The wandering hunter began to live in settled communities as food-grower Centuries passed Villages and cities grew up Architecture and industry progressed rapidly Some of the great ancient civilizations such as those of Egypt and the Indus valley belonged to that age

The Metal Age started about 3,000 B.C. with the use of bronze, and subsequently from about 1,400 B.C with the use of iron, there was a large scale urbanization. Facilities for transporting and storing food improved, and with all this the world population started rising, though slowly. During the last two hundred years, since the beginning of the industrial revolution, the rate of growth of world population has gone very high The population of the Indian subcontinent (India and Pakistan) has increased more than three-fold during the last 100 years. Today the total population of India alone is 430 million and that of the world is about 3,000 million.

THE HUMAN ORGANISM

Although man ranks supreme among all animals, and has an upright posture, his main systems, namely, nervous, circulatory, digestive, excretory, respiratory and reproductive systems, are the same as those of most other vertebrates The skin, muscles and a part of the skeleton together enclose the body cavity or coelome This is divided into two chambers by a muscular **diaphragm** (Fig. 28 20) Above the diaphragm is the **chest cavity** which encloses the lungs and heart, below the diaphragm is the **abdominal cavity** which contains most other organs The organs of the entire body cavity are together spoken of as **viscera.** The major part of the nervous system is enclosed in the cavity formed by the skull and vertebral column

Skin

The skin covers the entire body and protects the deeper tissues. Without it there would be mechanical injuries to the soft tissues, harmful bacteria would readily invade, and the body fluids would escape. The skin also perceives the senses of touch, pain, pressure, heat and cold. It regulates the temperature of the body, removes certain waste matter in the form of sweat, and manufactures vitamin D with the help of sunlight. It also serves to store extra fat

The skin is formed of two primary layers—epidermis and dermis (Fig 28 21). The epidermis itself is made of many layers of cells The layer just on the surface has dead, flattened, horny cells. When you scratch the skin, the scaly material which comes off is actually a scraping of these dead cells Below this horny layer is the growing layer which continues to replace the outer sloughed off cells The nails too are made of the dead horny material derived from special cells of the growing layer of the epidermis

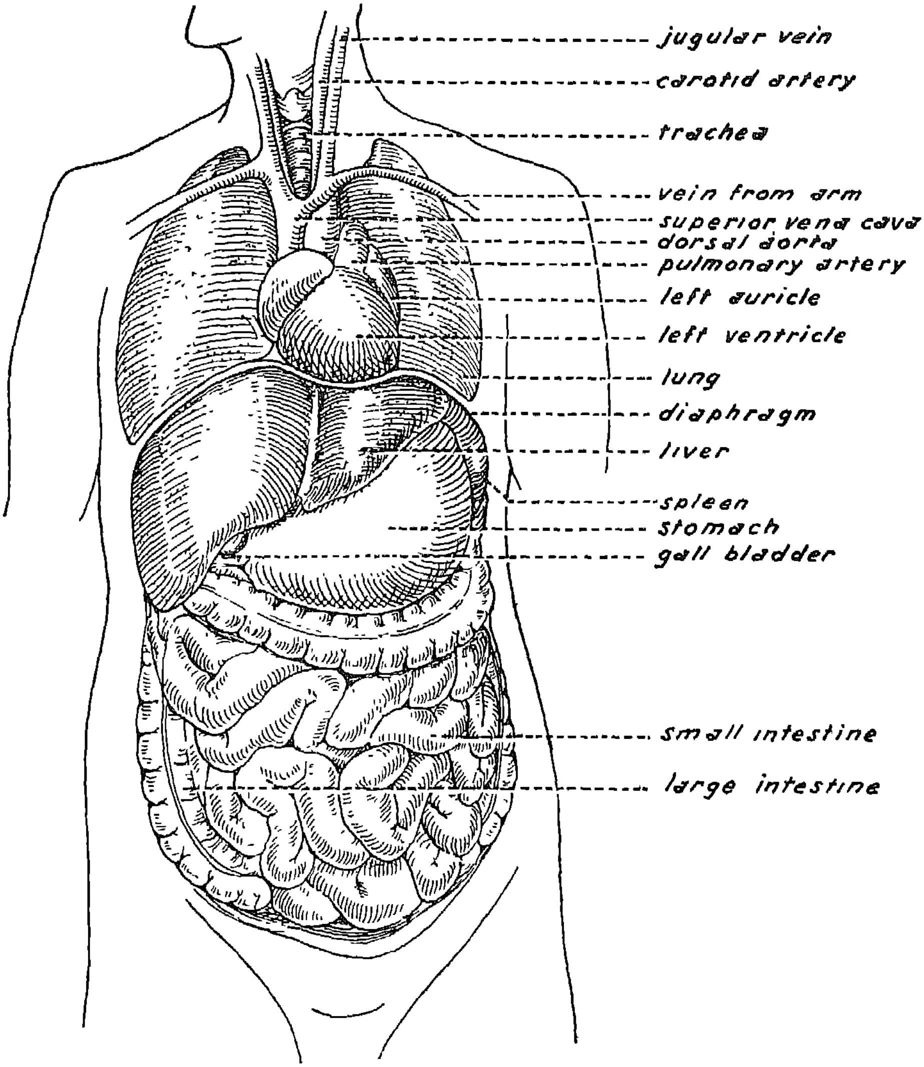


Fig. 28.20. The disposition of various internal organs viewed from the ventral side. After W C. Beaver, *General Biology*, The C V Mosby Company, St. Louis, 1962.

The inner layer called dermis is composed of a dense connective tissue with network of blood vessels, nerve fibres and skin glands. The **sweat glands** form coiled knots in the inner part of the dermis and a fine tube from each of them opens on the **sweat pore** on the outer surface. The sweat helps in regulating the temperature of the body through the cooling effect of its evaporation Incidentally, the sweat glands also remove certain salts and excretory substances such as urea in a small quantity. People living in hot countries, as in India, possess a larger number of sweat pores per square millimetre of the skin surface than those living in colder regions.

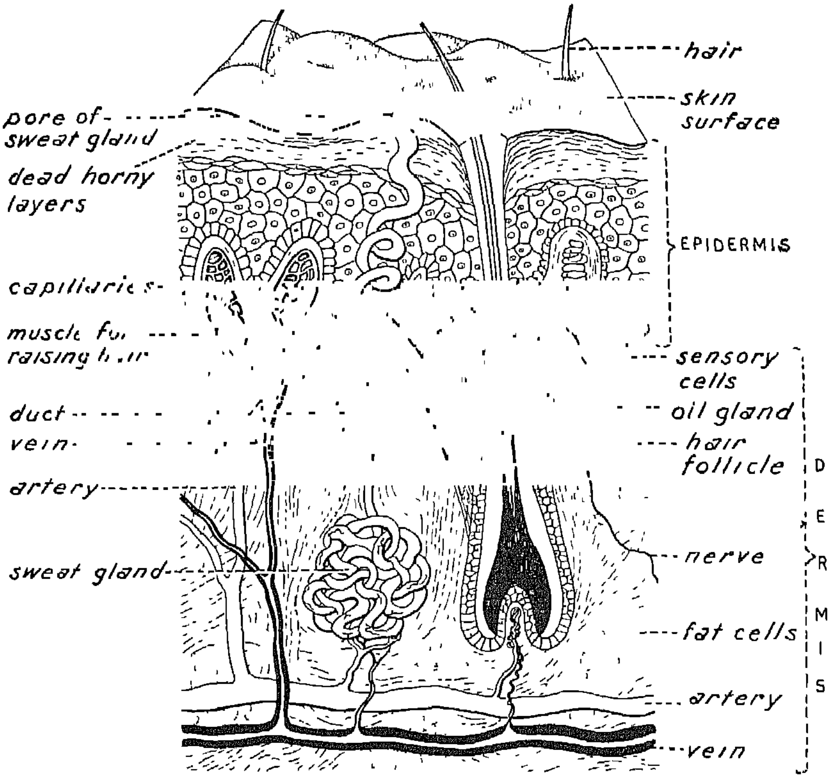


Fig. 28.21. Vertical section of human skin showing the dermis, epidermis, hair, sweat gland and oil gland. From various sources.

The **oil glands** are usually associated with the hair follicles They are formed by an inward extension of the inner layer of the cells of the epidermis They secrete a natural oil which flows over the hair and then to the skin surface. The dryness of the skin in cold weather results from the reduced activity of the oil glands.

The **hairs** are special outgrowths of the epidermis with their roots buried deep in the dermis. The hairs on the human body are believed to be gradually decreasing, but a thick hairy coat was characteristic of the primitive man. Long hairs on the scalp grow continuously. Those on the eyebrows, on the margins of the eyelids, in the nostrils and in the external ear canals have a limited growth and a protective function. Certain regions such as lips, soles and palms are hairless Graying of the hair is due to lack of pigment formation With age, chiefly in men, there is a tendency to losing hair leading to baldness. Baldness may be due to certain diseases of the scalp or it may simply be a hereditary character.

The colouration of the skin results from the presence of different pigments in the dermis and from the distribution of blood capillaries. The different races of man have different amounts of pigments. People living in more severe sunlight tend to have a darker skin.

Skeleton

The principal regions of the human skeleton (Fig 28 22) are the same as those of frog (*see* page 241), but a notable difference is the presence of **ribs** in man. Leaving the three tiny bones in each ear, our skeleton contains exactly 200 bones The brain box

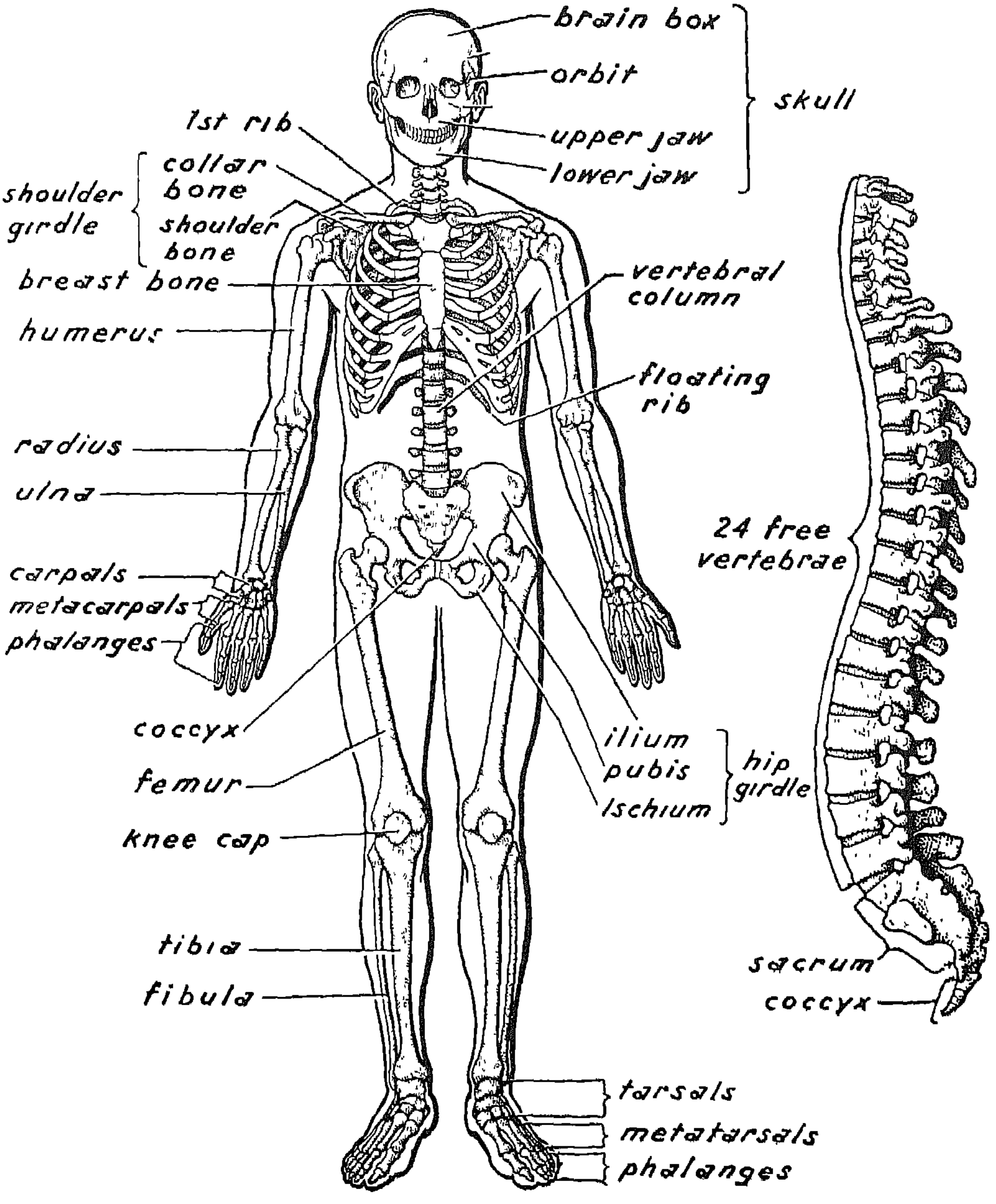


Fig. 28.22. The human skeleton (front view) and the vertebral column viewed from the left side. From W F. Pauli, *The World of Life: A General Biology*, Houghton Mifflin Company, Boston, 1949.

is exceptionally large and is formed of several flat, curved bones. In the adult, these bones are tightly locked together, but in a baby they are soft and incompletely united The face has 14 bones, but only the lower jaw is movable The backbone has 24 free vertebrae, a **sacrum** (made of five fused vertebrae) and a **coccyx** (made of four fused bones) which is a vestige of the tail

There are twelve pairs of ribs which constitute the **thoracic basket** protecting the delicate lungs and heart. Each rib is joined to the backbone and curves round the chest to form a cage The upper seven pairs of ribs are connected to a long central breast bone The next three pairs are connected to the rib above each The last two pairs are free and are called 'floating ribs'.

The shoulder girdle contains a collar bone and a **shoulder blade** on either side. The arm and hand contain 30 bones The hip girdle is made of a pair of large bones forming a trough which bears the weight of the trunk and supports the abdominal organs. Some thirty bones make the leg and the foot In addition to the true bones enumerated above, there are several extra **sesamoid** or 'seed-shaped' bones. One of these is the knee-cap which one can easily feel on the knee when the leg is in a relaxed position.

Digestive System

The digestive system begins with the mouth which has several specialities. The lips close the mouth, help in speech, and also receive some sensations (especially those of touch and warmth) The tongue moves actively during chewing and swallowing It perceives taste, removes food particles from the teeth after eating, and also helps in speaking. The roof of the mouth cavity, the **palate**, is hard in the front and soft at the back. A soft knob-like **uvula** hangs down from the back of the palate into the throat.

There are 32 teeth in an adult (Fig 28 23) They help not only in chewing the food but also in maintaining the shape of the face Many of you may not have cut the four 'wisdom teeth' which usually appear only after the seventeenth year. The teeth are of different sizes and shapes On the front are the **incisors**, four in each jaw, having straight, sharp biting edges. Next come the **canines**, one on each side They are conical in shape and help in tearing (this function is not so important in man but in the beasts of prey, like lion and cat, the strong canines are used for tearing the flesh) Following the canines are the five grinding teeth on each side. They have somewhat flat surface bearing ridges and grooves The first two of these are smaller and are called

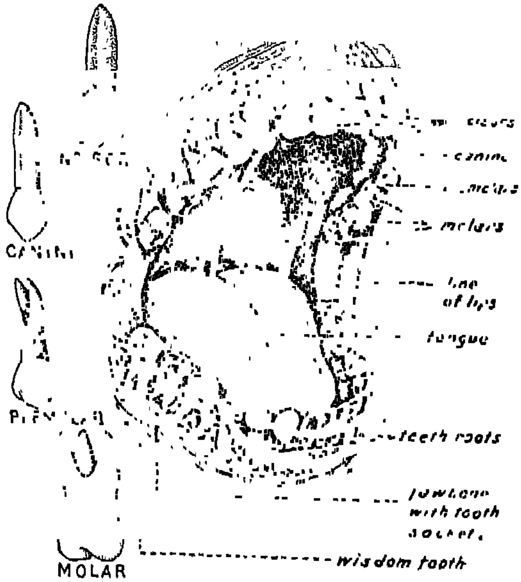


Fig. 28.23. A diagrammatic representation of the different types of human teeth and their position. After *Understanding Science*, Vol 3, No 27, Sampson Low, Marston & Co., Ltd., London, 1962.

premolars. The last three are the strong **molars.** The last molar of each side is called **wisdom tooth.**

You had a different set of teeth when you were a child These so-called **milk teeth** did not include the twelve molars (three on each side in each jaw) since they develop only once in the life of every human being The milk teeth usually start appearing between the age of six months and two years. Generally they begin falling in the sixth year. and are replaced by the permanent or adult teeth

A typical tooth has three regions the root, the neck and the crown (Fig 28.24) The crown is the visible part projecting above the gum The neck is the small region at the gum line. The root is firmly fixed in a cavity or **socket** of the jaw bone. The main substance making the tooth is **dentine.** The exposed part of the tooth is coated with a very hard substance called **enamel.** A kind of cement and fibrous membrane strengthen the fixation of the tooth The root has a narrow basal opening which leads into a small pulp cavity. This cavity contains small nerves and blood vessels which enter it through the basal opening The incisors and canines have a single root, but the premolars have two and the molars have three roots each. Our teeth perform hard work everyday but they hardly get worn out because the crown is covered by the hard enamel.

Good teeth not only add to one's looks but are also an asset to good health They should be brushed at least twice a day and if possible after every meal The food particles left in the spaces between the teeth undergo decay and form an acid which affects the enamel The acid also causes cavities in the teeth. For keeping the gums and teeth healthy, your food should contain adequate amounts of calcium and vitamins. Vitamin C, which is available in fresh fruits and vegetables, prevents **scurvy** (a disease marked by bleeding and swelling of the gums). Vitamin D or the so-called sunshine vitamin is necessary for the proper formation of teeth.

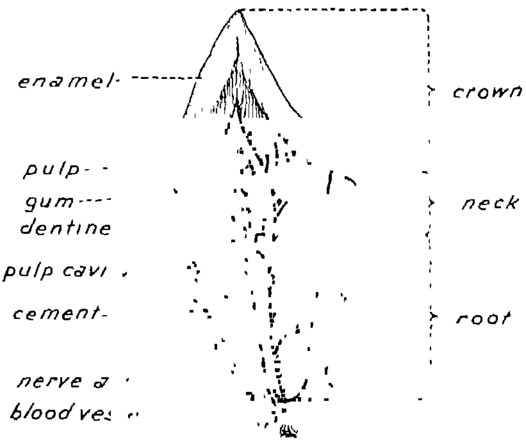


Fig. 28.24. An incisor in longitudinal section. After E Kroeber, W H Wolff and R L Weaver, *Biology*, D.C Heath and Company, Boston, 1960

Three pairs of **salivary glands** are associated with the mouth. One pair is situated in the angles of the lower jaw, another pair is placed within the floor of the mouth below the tongue, and the third pair occurs in the cheeks in front of and below the ears (Fig. 28 25). These glands

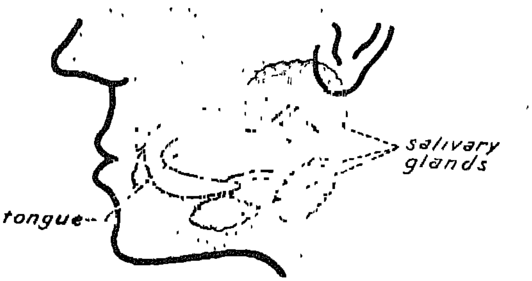


Fig. 28.25. The disposition of the salivary glands. After P B Weisz, *Biology*, McGraw-Hill Book Company, Inc., New York, 1954.

secrete **saliva** which is poured into the mouth cavity through ducts. Sometimes the third pair of salivary glands swells up due to infection by a virus resulting in a disease called **mumps.**

The saliva is a clear watery fluid which lubricates the mouth, cleanses the teeth and helps in chewing and swallowing the food. It partly converts starch into sugar. You may have experienced that if a piece of bread is chewed a little longer than usual, it starts tasting sweeter. The lubricating action of saliva also helps in speech. There is difficulty in speech when the mouth becomes dry due to excitement or fear.

The tongue and cheeks push the chewed food into the throat or pharynx. There are several openings in the throat, such as those of the nasal chambers, the eustachian tubes (from the ears), and the windpipe. But things are so adjusted (Fig. 28.26) that the food enters only the foodpipe (oesophagus). If, by chance, the food enters the windpipe you begin to cough and thus clear it of the entered stuff.

The foodpipe or oesophagus is a long, straight tube connecting the throat with the stomach (Fig. 28.27). Once the swallowed food enters the oesophagus it is continuously pushed behind by a wave of contraction (peristalsis) resulting from the action of muscles lining the walls of the alimentary canal.

The stomach is an elastic bag held just beneath the diaphragm. In an average person it can hold about two to three litres of food. The wall of the stomach is highly glandular and pours its secretion directly into its cavity. Powerful waves of contraction in the stomach wall churn the food and break it into smaller bits. These contractions also mix the juices of the stomach with the food which now acquires a creamy consistency and is called **chyme.** At the junction of the stomach with the small intestine there is a narrow passage (**pylorus**) guarded by a valve. This valve opens intermittently to release the chyme into the small intestine. The stomach empties in three to four hours after a meal.

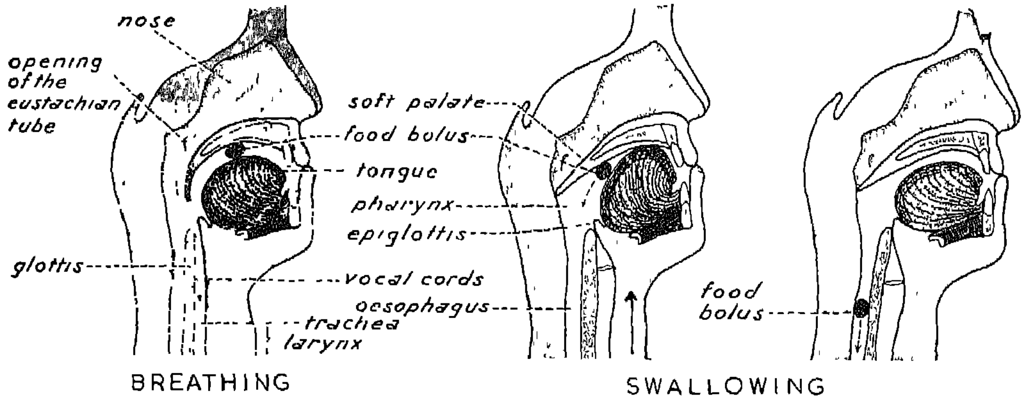


Fig. 28.26. The position of tongue and epiglottis during breathing and swallowing. The tongue pushes the bolus into the pharynx. The air passage is closed by the epiglottis. The larynx moves upward and the bolus enters the oesophagus. After C.A. Villee, *Biology*, W.B. Saunders Co., Philadelphia, 1957.

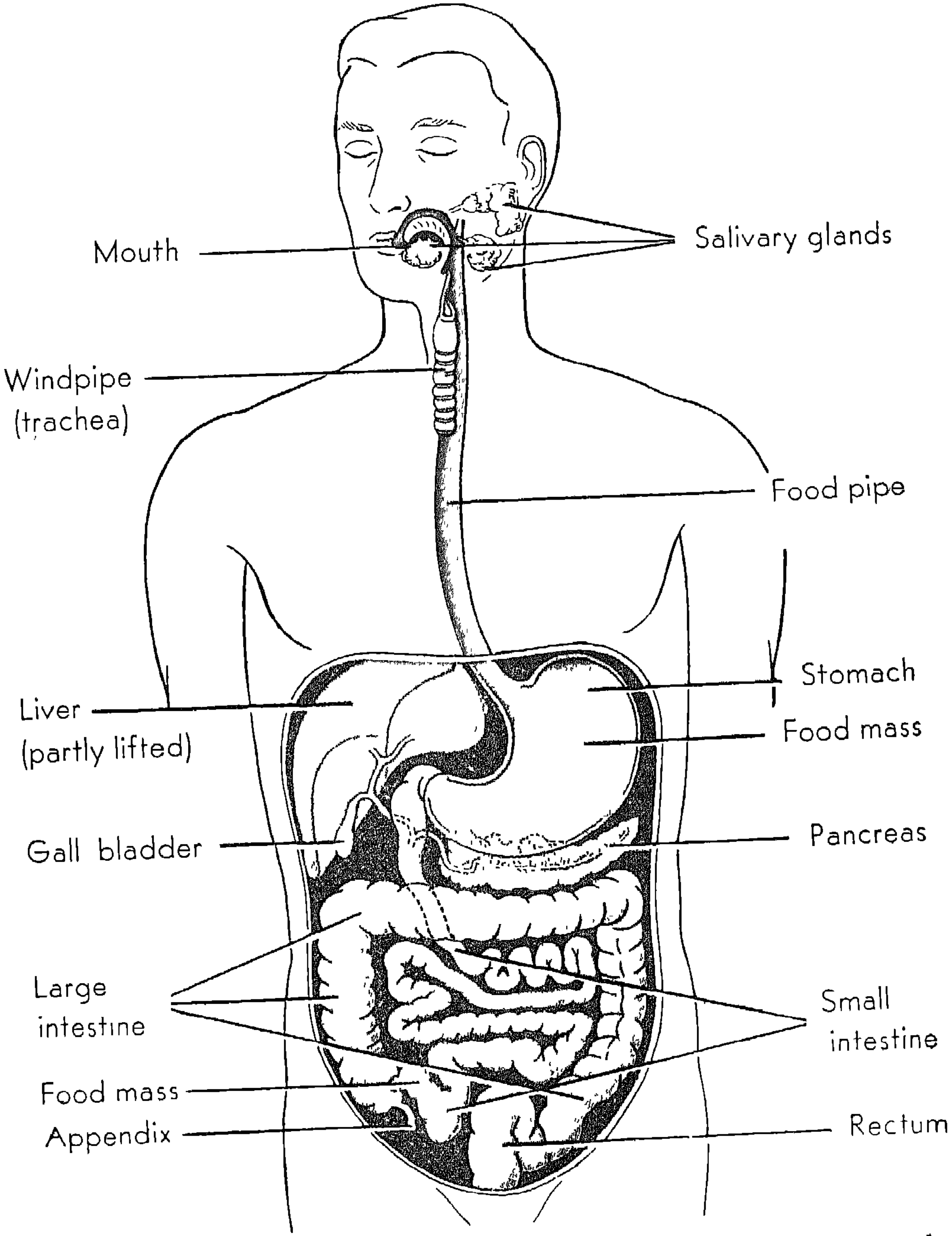


Fig. 28.27. The digestive tract and the glands that help in digestion. The organs are not drawn in exact proportion or position. From E. Kroeber, W.H. Wolff and R L Weaver, *Biology*, D.C. Heath and Company, Boston, 1960.

The small intestine is a long, narrow, coiled tube about seven metres long and nearly 2 5cm wide Its first segment, about 25cm long, is called the duodenum. The inner lining of the intestine bears numerous microscopic finger-like processes (**villi**) which present a velvety appearance (Fig 28.28) and secrete digestive juices. The small intestine continues into the large intestine or colon in the lower right region of the abdomen. At the junction of the two there is an enlarged pouch from which arises a small finger-like process, the **vermiform appendix.** The appendix is a vestigial organ in man, i e it was once functional but has since lost its utility and is generally reduced Sometimes the appendix becomes inflamed, producing a disease called **appendicitis** and the usual treatment is its surgical removal. The large intestine is usually 1.5 metre long and about 7 5 cm wide.

The intestines undergo rapid and rhythmic contractions so that the digestive juices get thoroughly mixed with the food. By the time the chyme reaches the large intestine it has become quite fluid It moves along rather slowly and most of its water is absorbed into the blood stream The contents of the large intestine gradually attain a semi-solid consistency and are passed as faeces into the next region, the short muscular rectum The rectum opens to the exterior at the anus.

If the contents move very slowly, which may be due to the lack of roughage in the diet, too much water is absorbed from the intestines and the faeces become dried and hard resulting in **constipation**. The opposite condition, where the contents move too quickly (due to irritating substances or infections), results in a poor absorption of water which consequently causes **diarrhoea**.

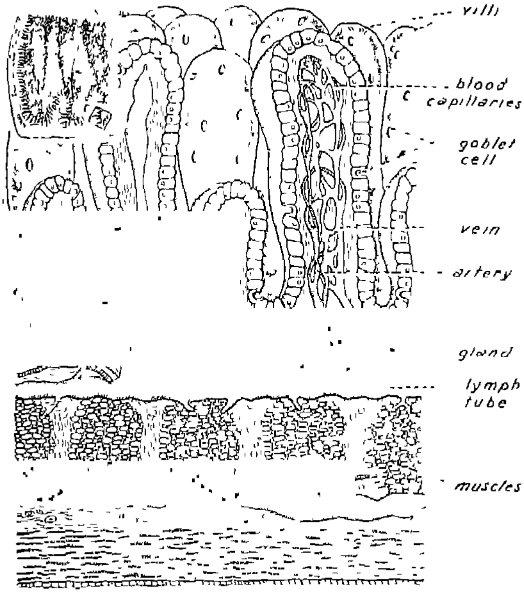


Fig. 28.28. **Structure of the intestine. The inset shows the velvety inner surface of a piece of intestinal wall. The main figure is a highly enlarged view of a vertical section of the intestinal wall. Note the glandular nature of the villi.** Modified from G.G. Simpson, C S. Pittendrigh and L H Tiffany, *Life· An Introduction to Biology*, Harcourt Brace and Company, Inc , New York, 1957

Associated with the intestines are two important glands, the liver and pancreas. The liver is the largest gland in our body. It consists of the right and left lobes located just below the diaphragm, mostly on the right side It produces a brownish-green fluid, the bile, which flows through a series of bile ducts into the gall bladder where it becomes concentrated. The lower part of the duct brings the bile from the gall bladder into the duodenum The bile contains certain salts and pigments. The digestive and other functions of the liver are enumerated on page 317. The pancreas is a long, many-lobed, whitish gland lying just behind the stomach It is much smaller than the liver and produces a digestive juice, the pancreatic fluid, which is poured into the duodenum through a common opening with the bile duct. The pancreas also produces a hormone called insulin (*see* page 333).

Process of digestion. As you may be aware, our food comprises six groups of nutrients carbohydrates, fats, proteins, minerals, vitamins and water The minerals and water-soluble vitamins are directly absorbed through the intestinal walls, but the other substances have to be broken down into such simpler components as can be readily absorbed through the walls of the alimentary canal. The basic process of digestion is hydrolysis in which large, complex molecules are broken into smaller component molecules by the introduction of water. Each hydrolytic reaction in digestion is brought about by an enzyme which acts like a catalyst.

Unlike in frog, the digestion of food in man begins right in the mouth. The saliva contains **ptyalin** which initiates the digestion of starch by breaking it into double sugars (disaccharides). Upon reaching the stomach the food is mixed with the highly acidic gastric juice. The hydrochloric acid present here facilitates the action of **pepsin**, the principal enzyme of the gastric juice. The acid also kills any harmful bacteria entering along with food Pepsin converts the proteins (long chains of amino acid molecules) into peptides (shorter chains of amino acids)

When the food enters the intestine its digestion has only started. It contains unchanged fats, unchanged sugars, some starches which were not acted upon by ptyalin, coagulated milk or casein, peptides formed due to the action of pepsin of gastric juice, and some proteins still unchanged by pepsin. Bile, the secretion from liver, serves two functions in the process of digestion. First, it neutralizes the hydrochloric acid from the stomach: this is important because the pancreatic juice acts only in an alkaline medium. Secondly, it emulsifies the fats or breaks them into very fine droplets, thus permitting better action by fat-splitting enzymes. Very fine droplets of fats may even be absorbed directly without preliminary digestion

The pancreatic juice is a clear alkaline fluid which contributes in neutralizing the acid chyme. It contains three digestive enzymes: **amylopsin** which continues the breakdown of the starches into disaccharides, **trypsin** which breaks the remaining molecules of protein into peptides, and a **lipase** which converts the fats into fatty acids and glycerol that are easily absorbed

The glandular wall of the intestine secretes a highly alkaline fluid It contains four principal enzymes as follows **Erepsin** completes protein digestion by changing peptides into amino acids that are readily absorbed. **Maltase** breaks maltose into glucose **Lactase** similarly converts milk sugar (lactose) into glucose. Another disaccharide, sucrose, is split by **sucrase** into glucose and fructose

As the food passes through the intestine, most of the digestible substances of the food are reduced by the enzymes to a state in which these can be absorbed. Most of the digested food is absorbed in the small intestine or ileum. The large intestine absorbs most of the water from the chyme and the residue passes into the rectum as faeces.

Blood and Its Circulation

An average person has about 6 5 litres of blood in his body Its components are more or less similar to those in the blood of frog. The straw-coloured plasma is nine-tenths water containing many substances in solution. The most important of these are serum globulin (which gives rise to antibodies), various minerals, digested food (blood sugar, fatty acids, amino acids, etc.), excretory products (chiefly urea), **prothrombin** (a substance that initiates clotting), and **fibrinogen** which brings about a clotting of the blood

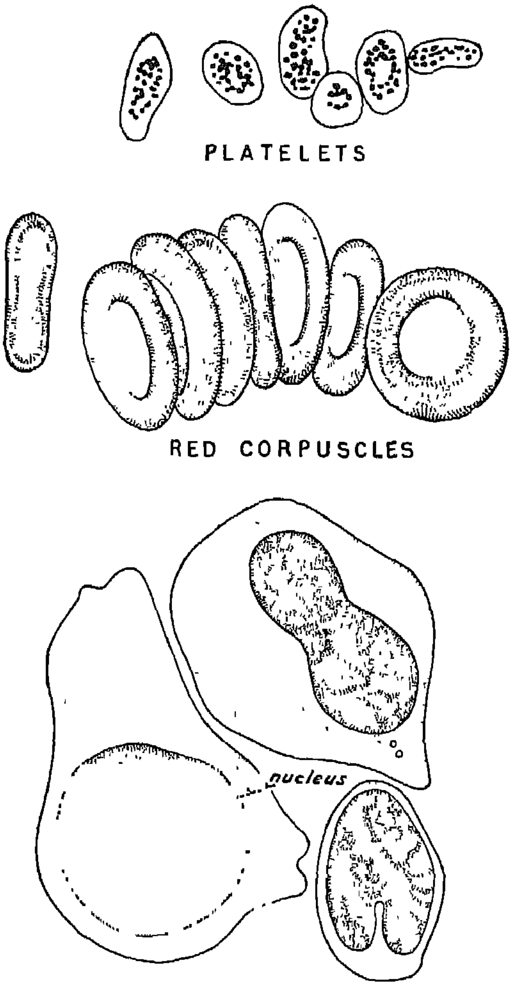


Fig. 28.29. The solid components of human blood. The mature red blood corpuscles are enucleate whereas the white corpuscles contain nuclei. After E. Kroeber, W H Wolff and R L Weaver, *Biology*, D C Heath and Company, Boston, 1960

The solid components include the red and white blood corpuscles and the platelets (Fig 28 29) The red blood corpuscles are in the form of biconcave discs When mature, they lack nuclei although a nucleus is present in each in the early stages of development The blood of an average person contains about 25,000,000.000,000 red blood cells They contain haemoglobin which can readily pick up oxygen and deliver it to the parts of the body that are deficient in it The red blood corpuscles carry oxygen from lungs to all the other parts of the body

The white blood corpuscles, or leucocytes, are more or less colourless They are larger than the red corpuscles and contain a nucleus They can move about like an amoeba and pass through the capillary walls into the lymph or tissue fluid They are fewer in number, there being usually one white corpuscle to every 600 red corpuscles. They are produced in bone marrow and in lymph glands. Their main function is to destroy harmful bacteria and to remove some other foreign material from the tissues and blood When the body is infected with bacteria, the white corpuscles increase in number.

The blood platelets (thrombocytes) are very small, even smaller than the red blood corpuscles. They are irregular, colourless bodies probably formed in the bone marrow They too are important in the formation of blood clots

The heart. This is a conical organ about the size of the fist. It lies above the diaphragm between the two lungs, almost in the middle of the chest but somewhat tilted at its apex to the left (Fig. 28.30) It is enclosed in a double-walled membranous sac, the pericardium. The heart is a very remarkable organ that keeps working all the 24 hours throughout the life of

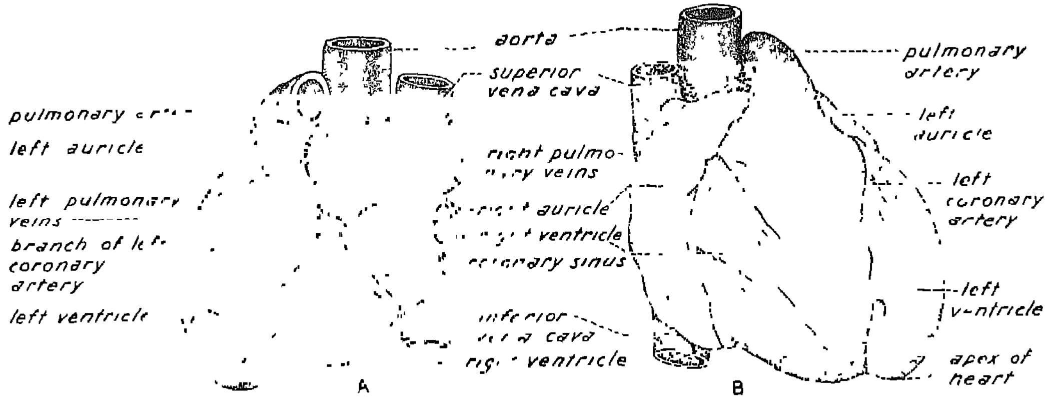


Fig. 28.30. The dorsal (A) and ventral (B) views of the heart. A After C C. Francis, *Introduction to Human Anatomy*, 1964 B After C C Francis, G C Knowlton and W W Tuttle, *Textbook of Anatomy and Physiology*, 1958 The C V Mosby Company, St Louis

an individual If it stops for more than 10 minutes life usually comes to an end The heart of an average person at rest beats 70 to 80 times a minute

The right and left halves of the heart are completely separated by a septum. Each half has an upper chamber or the auricle and a lower chamber or the ventricle Each auricle opens into the ventricle of its own side through an auriculo-ventricular aperture The two apertures are guarded by valves which can open only into the ventricles (Fig. 28 31). The right auricle receives venous (deoxygenated) blood from the body (except the lungs) through two main

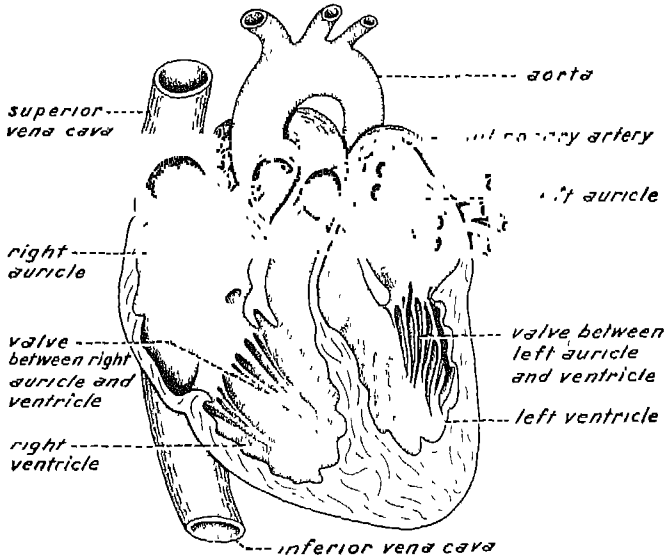


Fig. 28.31. Vertical section of the heart. After W C Beaver, *General Biology*, The C V Mosby Company, St, Louis, 1962.

vessels—a superior vena cava and an inferior vena cava. The former brings blood from the upper regions of the body and the latter from its lower parts. The left auricle receives the oxygenated blood from the lungs through four pulmonary veins (Fig. 28 32)

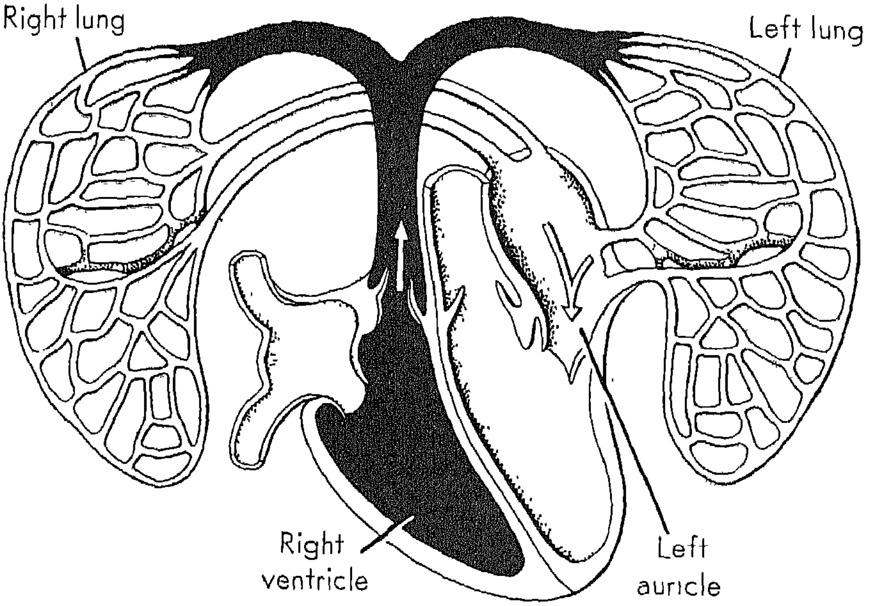


Fig. 28.32. Circulation of blood from right ventricle to left auricle. The right auricle is shown as though it were empty at this time but actually it is filling up with blood from the rest of the body. Notice how blood from the right ventricle goes only to the lungs. From E Kroeber, W H. Wolff and R L. Weaver, *Biology*, D C Heath and Company, Boston, 1960

The ventricles are highly muscular and the left one is even more so. They receive blood from the respective auricles. When the ventricles contract the blood is forced into the arteries. The presence of valves prevents it from flowing into the auricles. The right ventricle pushes the blood into a large pulmonary artery which soon divides into two branches leading to the respective lungs (Fig. 28 32). The left ventricle pumps the blood into a thick **aorta** or the main distributing artery When the ventricles relax and regain the original size they draw more blood from the auricles Once pumped away from the ventricles the blood is prevented from returning by the valves located at the base of the pulmonary artery and the aorta These valves open like trap doors so that the blood can flow in only one direction Figure 28.33 shows the circulation of blood from the left ventricle to the body and back again to the right auricle.

The arteries and veins. The aorta is the main distributing artery of the body. Its first branches are the fine coronary arteries that supply blood to the heart muscles (coronary thrombosis, one of the common types of heart attack, is due to the blocking of the coronary arteries). The aorta then curves upwards and backwards, and travels along the backbone (Fig. 28.34) From the upper part of the curve of the

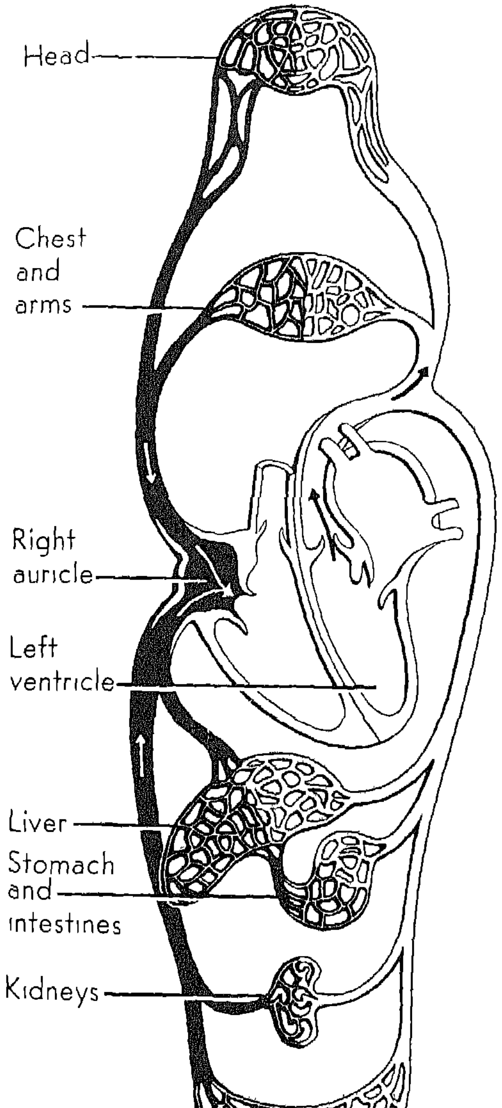


Fig. 28.33. Circulation of blood from the left ventricle to the right auricle. The left ventricle pumps blood into the aorta which in turn supplies the other parts of the body. The venous blood from various organs of the body comes into the right auricle through the superior and inferior vena cavas. It is finally pumped by the right ventricle into the lungs for purification. Blood can flow from auricles to ventricles but its backward flow is prevented by valves. From E Kroeber, W H Wolff and R.L. Weaver, *Biology*, D.C. Heath and Company, Boston, 1960

aorta arise three blood vessels which supply the right and left arms, the neck and the head Along the rest of its path the aorta gives off branches to the muscles of the chest, to the food canal, liver, kidneys and gonads Finally it divides into two main arteries going to the legs

The veins collecting blood from the legs join to form the **inferior vena cava.** The latter in its course towards the heart receives veins from the back, gonads, kidneys and liver (Fig 28 34) The blood returning from the food canal is first brought to the liver by a portal vein and after undergoing certain important changes therein (such as deposition of excess of sugars in the form of glycogen) it is poured into the posterior vena cava through the hepatic veins The blood from the upper parts of the body is collected by a number of smaller veins which unite to form the paired **innominate veins.** These in turn join to form the large **superior vena cava** that opens into the right auricle. The coronary vein returns the blood collected from the walls of the heart As the blood circulates through various organs of the body, it receives or delivers certain substances. Its composition thus keeps on changing as illustrated in figure 28.34.

Pulse and blood pressure. Many a time you must have seen a doctor using a stethoscope to 'feel' the heartbeats of a patient. This enables him to assess the working of the heart Each heartbeat results from a contraction (**systole**) and an expansion or relaxation (**diastole**) of the heart During diastole the two auricles become filled with blood poured into them by the veins In systole the blood is pumped out of the heart into the arteries. The two processes take a total of about 0.8 seconds so that you can feel nearly 75 beats per minute. The beating of

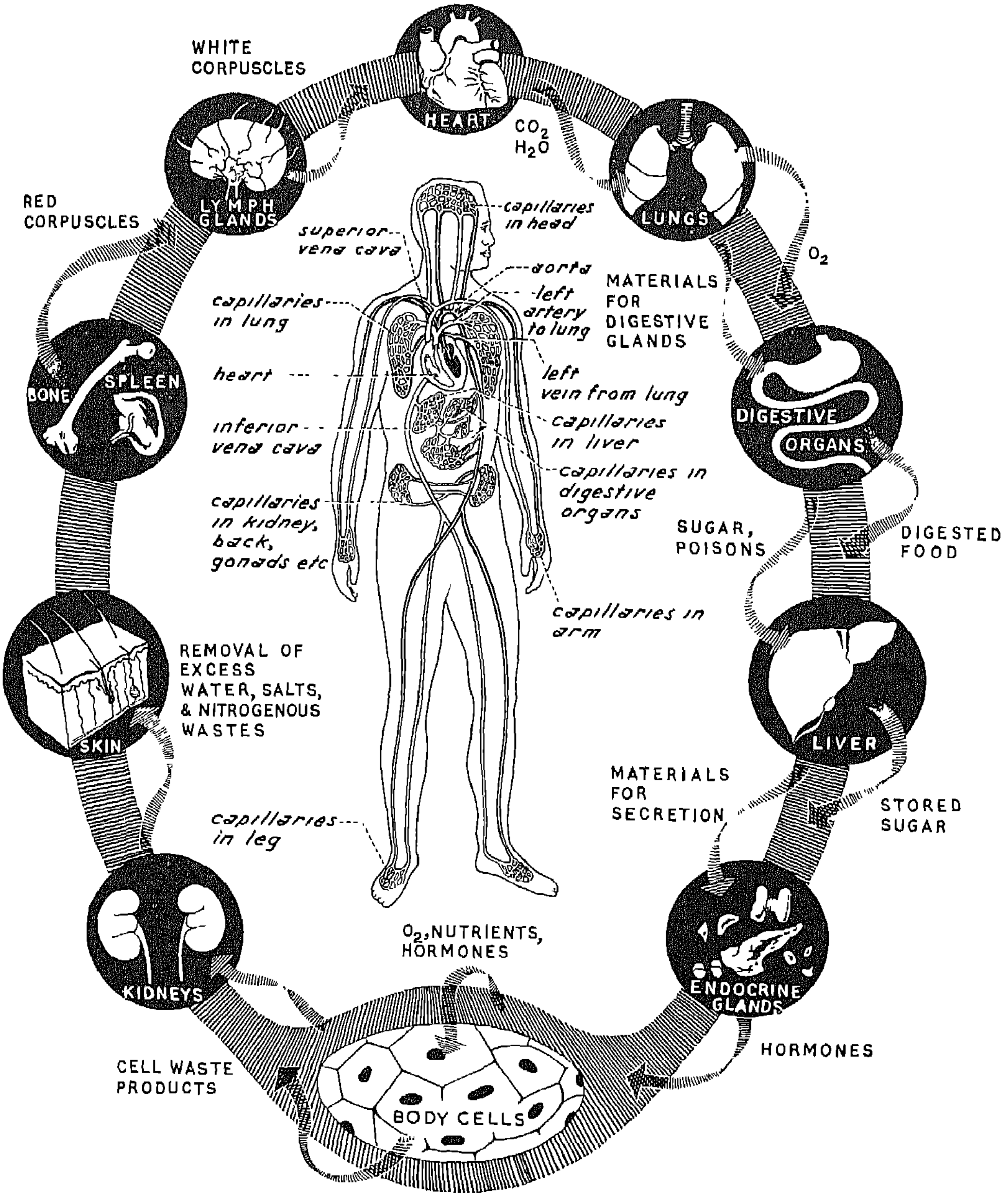


Fig. 28.34. **Changes in the composition of the blood as it flows through the various parts of the body. By its pumping action the heart keeps the blood stream flowing. The lungs remove carbon dioxide from the blood and enrich it with oxygen. The small intestine delivers digested foods to the blood stream. The liver removes wastes, stores sugars and re-delivers them when needed. The ductless glands pour their secretions (hormones) into the blood. The body cells pick up food and oxygen and deliver their waste products. The skin and kidneys remove excess water and dissolved wastes. The spleen filters the worn out red blood cells while the bone marrow delivers fresh red cells. The lymph glands accumulate large numbers of white blood cells to combat germs. The central diagram shows the main arteries and veins.** After C. Gramet and J. Mandel, *Biology Serving You*, Prentice-Hall, Inc., Englewood Cliffs, New York, 1958.

the heart is also felt in the arteries as regular jerks or pulse. When the ventricle suddenly pushes the blood into the arteries the latter undergo extra distension owing to the additional amount of blood. This distension causes pulsation in the arteries. You can feel your pulse wherever the arteries lie near the surface as on the wrist, neck and temples.

The flow of blood in the arteries exerts a pressure on their elastic walls. This pressure is greater during a systole than during diastole. The two pressures (systolic and diastolic) are usually measured in terms of pressure exerted on a column of mercury. In a normal adult the **blood pressure,** or the systolic and diastolic pressures, are 120 and 80 mm Hg respectively. It is expressed as 120/80 mm Hg.

The blood types. You might have seen or heard that whenever there is much loss of blood due to some injury, the life of the injured person may be saved by replacing the lost blood with the blood of some healthy person (donor). However, the blood from just any healthy person would not do. Quite often it happens that the blood of one person does not mix with that of the other. Instead, the two bloods form clumps. As a result of the work of a German biochemist, Karl Landsteiner, and others, it is now known that there are four types of blood named A, B, AB and O depending upon the presence or absence in the red blood corpuscles of one or both substances called A and B. People with O type of blood are **universal donors.** Their blood lacks both A and B substances and can be safely transfused into any other person. People with AB type are **universal recipients.** The blood of the donor is 'typed' and matched with the blood of the patient before transfusion (Fig 28.35).

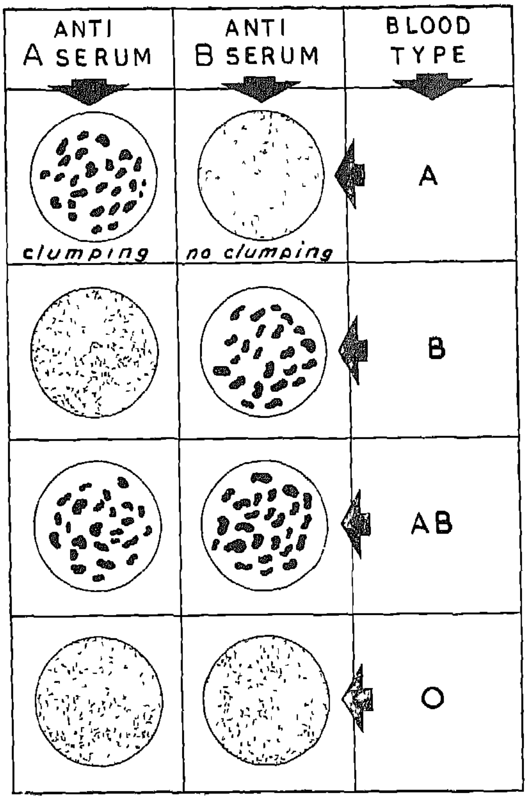


Fig. 28.35. Diagram showing the method of determining blood groups. A drop of the given sample of blood is mixed separately with serum containing an anti-A or anti-B substance. The antiserum that brings about clumping of the sample gives the blood type. After E.D. Hess and R.H. Lape, *Biology—A Basic Science*, D. Van Nostrand Company, Inc., New Jersey, 1958.

Care of the circulatory system. For proper functioning of the different parts of the body, it is essential that they are adequately provided with food and oxygen. This is possible if we keep the circulatory system healthy. To do this the most important thing is to regulate the food habits. Adequate quantities of proteins, iron and vitamins are essential for the production of blood. Regular exercise helps in the smooth circulation of blood The blood cells continue to be formed and destroyed in our bodies. An average red blood cell lives for about four months. About 10,000 red blood cells are destroyed every second! If this loss is not made good, a diseased condition called **anaemia** may result. The skin looks yellowish and the person becomes weak and lazy A similar condition sometimes develops due to the deficiency of haemoglobin in the corpuscles. This results from a lack of iron in the body.

Special attention must be paid to the heart since it works throughout life Modern life, full of tensions and worries, often results in high blood pressure or hypertension. This means the heart is forced to do more work than it is capable of and may give way any time. It is important, therefore, that we should keep our emotions under control.

Clotting of blood. Since the blood flows under pressure in closed channels, the slightest break in the system causes the blood to escape just as water escapes from a broken pipe Clotting of blood provides a method for stopping this leakage Everyone would have experienced a small cut or bruise somewhere on the body The blood oozes out for a short while and then it gradually stops coming out when a clot is formed at the site of the injury. Clotting is brought about by a series of chemical reactions in the blood The damaged cells release an enzyme **thrombokinase** The blood platelets break down on coming in contact with a foreign surface outside the circulatory system, and they also yield thrombokinase. This transforms the prothrombin of the blood into thrombin Thrombin acts on dissolved fibrinogen to produce fibrin which gets deposited as a fine network at the site of the injury The blood corpuscles plug the meshes of the fibrin network and the whole thing forms a crust which stops the flow of blood through the severed blood vessels.

Sometimes people suffer from the so-called bleeder's disease or haemophilia. This is a sex-linked character (*see* Section VI), resulting in a hereditary abnormality. Here the blood does not clot due to the absence of fibrinogen and the person may bleed to death even from slight wounds. In haemophilia usually the males suffer while the females act only as carriers.

Lymph and Lymphatic System

The lymph bathes the cells of all the tissues It mostly filters from the blood plasma through the blood capillaries. Although partly reabsorbed into the capillaries, most of it flows into a system of fine channels which repeatedly join to form larger ducts. Ultimately the fluid is poured back into some vein near the heart This additional system of vessels is called the lymphatic system (Fig 28 36) There are numerous enlargements in the lymph tubes, somewhat like beads in a string These are called the **lymph nodes.** Here the lymph tubes break up into fine branches once again, and the white corpuscles collect in large numbers in these nodes to fight any bacteria in the lymph The lymph nodes are very abundant in the neck, arm pit and groin. Sometimes you would have felt a painful swelling in the arm pit or in the groin. This is due to some infection in the limbs. The tonsils and adenoids at the back of the nose are also masses of lymphatic tissue. Occasionally the tonsils become inflamed and have to be surgically removed.

The lymph is almost similar to the blood plasma It is colourless or yellowish. It has no blood platelets but contains lymphocytes (small white blood corpuscles). Lymph has many functions in our body. It supplies food and oxygen to the tissues, and collects carbon dioxide and wastes from them, it helps in fighting against many pathogenic organisms; and it serves to equalize the body temperature.

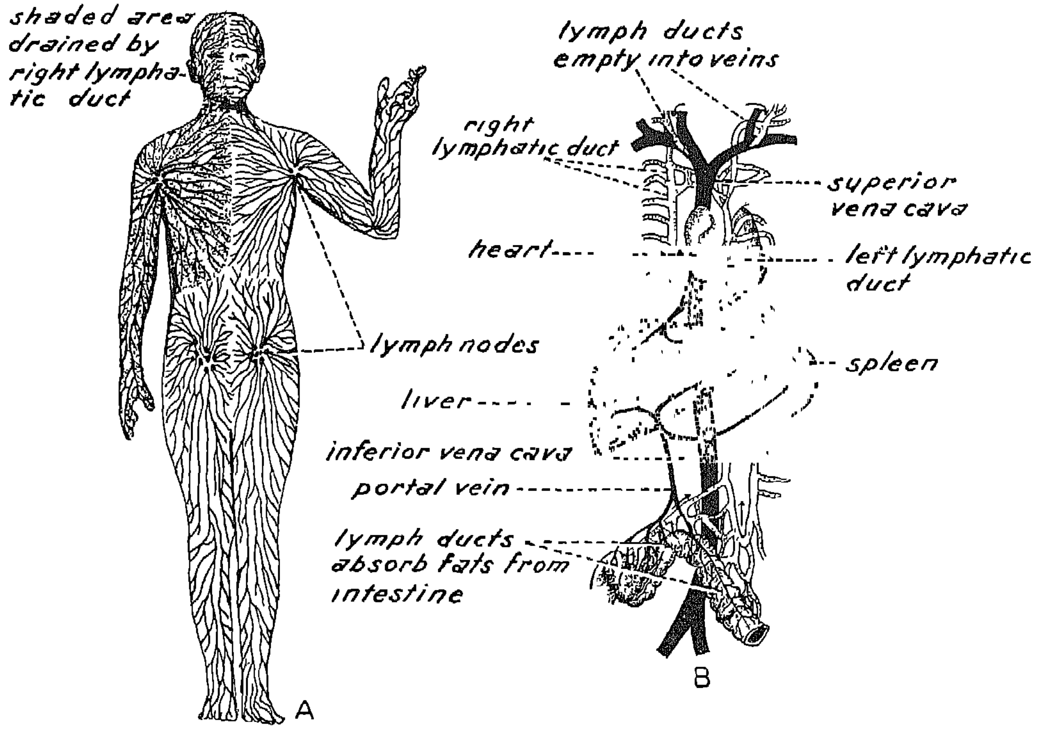


Fig. 28.36. The lymphatic system. A. Major lymph nodes in the body and areas drained by the left and right main lymphatic ducts. B. The relation of lymphatic vessels to parts of the digestive and circulatory systems. After A.O. Baker, L.H. Mills and J. Tanczos, *New Dynamic Biology*, Rand McNally & Co , New York, 1959.

Spleen and Liver

The spleen is a large organ, about the size of the fist, situated on the left side of the abdomen just below the diaphragm (Fig. 28 20). It is a spongy tissue with a rich blood supply. The spleen serves two main functions: it filters the disintegrated red blood cells from the blood flowing through it, and acts as a reservoir holding a lot of blood. Whenever there is haemorrhage (loss of blood) the spleen releases the reserve blood into circulation. In the human embryo it is also the site of formation of both red and white blood cells.

As you have already learnt, the liver is the largest organ in our body. It produces bile which has an important role in the digestion of fats. Besides this, the liver performs numerous other functions. In fact one might say that the liver is the greatest chemical factory in our body.

All the food material absorbed from the intestines into the associated blood vessels (excluding fats which are absorbed directly into the lymphatic system) is first brought into the liver by the hepatic portal vein. There it becomes distributed by means of a capillary network. The liver cells remove many substances from the blood, specially the carbohydrates and amino acids. The carbohydrates are stored as insoluble glycogen, or they are used in other biochemical processes. The glycogen may be reconverted into soluble sugars and released into the blood when needed. The amino acids may be used in the synthesis of certain blood proteins or they may be deaminated (this is a process of removing the amino group). The ammonia formed in the process is converted into urea which is ultimately removed by the kidneys.

The liver breaks down the haemoglobin of the dead and worn out red blood cells. Its iron and amino acids are reutilized by the body while the haeme portion is converted into bile pigments which are poured into the gut together with the bile and subsequently removed along with faeces. In jaundice (a disease in which the skin turns yellowish) the bile pigments increase in the blood stream. This may be due to either some obstruction in the flow of bile into the gut or due to an excessive breakdown of red blood cells.

You would now realize that a defect in any of these varied and extremely important functions of the liver would seriously affect the health.

Respiratory System

The respiratory system begins with a pair of nostrils. These are separated by a flexible, cartilaginous septum whose upper part is bony. The hairs and mucus of the nose remove dust from the air entering the nasal passages. Here the air is warmed and moistened. In breathing through the mouth, these advantages of nasal breathing are lost.

From the nasal chambers the air reaches the throat or pharynx (Fig. 28.37). Next it enters a cartilaginous voice box, or larynx, also called 'Adam's apple', which can be easily felt in the front part of the neck. There are two thin elastic vocal cords inside the larynx. They can be tightened by muscles and then vibrated by the air passing between them to produce sound. The glottis is the opening between the two vocal cords. It is protected by a leaf-shaped **epiglottis.**

The larynx leads into a long **trachea** or windpipe. Its walls are strengthened by a series of C-shaped cartilaginous rings. At about the middle of the chest the trachea divides into a right and a left **bronchus,** each leading to the respective lung. Inside the lungs the bronchi are repeatedly branched to form finer tubes, the **bronchioles.** Each bronchiole ends in a bunch of fine air sacs or alveoli. An air sac has a thin wall surrounded by a network of blood capillaries through which the exchange of gases takes place.

The lungs are cone-shaped, pointed at the top and broad at the bottom. Each lung is a light spongy structure consisting of millions of alveoli, bronchioles and blood vessels all of which are bound together by connective tissue into an elastic mass. Each lung is covered by two membranes—an inner pulmonary pleura that closely covers the lung and an outer pleura that also lines the diaphragm and the cavity of the chest. A thin layer of fluid separates the two membranes to reduce friction. Inflammation of the pleura causes a disease known as pleurisy. The most prominent symptom in the first stage of pleurisy is a sharp pain in the chest, which becomes more severe by deep breathing or coughing.

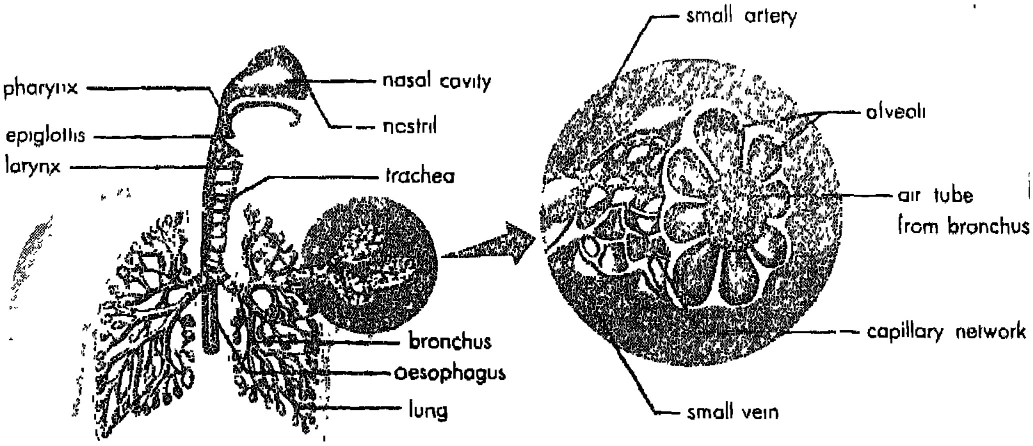


Fig. 28.37. Diagram showing the respiratory organs of man. The nasal cavity leads into the larynx through the pharynx. The trachea connects the two lungs with the larynx. The two bronchi divide repeatedly in the lungs and finally end in alveoli. Some of the alveoli are enlarged in the diagram on the right. Exchange of gases takes place between the blood in the capillaries and the air surrounding the alveoli. From *BSCS High School Biology*, Rand McNally & Co., New York, 1962

Breathing movements. Breathing or inhalation and exhalation is caused by the diaphragm and the ribs. During inhalation the diaphragm is lowered, and the ribs and breast bone are moved upward and outward by a set of muscles. The chest is thus expanded and the air rushes in (Fig. 28.38). The reverse happens during exhalation. The contraction of the muscles compresses the abdominal organs which push the diaphragm up The ribs and breast bone are also lowered. Thus the lungs are compressed and the contained air rushes out The action of the diaphragm in inflating the lungs can be roughly demonstrated by an experiment shown in the figure 28 38 Normally, both diaphragm and ribs take part but breathing by the diaphragm tends to predominate Stop reading for a while and just try to feel that your abdomen also dilates and contracts with inhalation and exhalation. The abdominal movements indirectly help in the rise and fall of the diaphragm. The extent of abdominal movements in breathing varies from person to person and even according to the position and activity of the same individual. When the lungs are fully inflated they hold about 3,000 ml of air. Ordinarily only 500 ml of air is breathed in and out.

In certain situations, as in cases of drowning, severe electric shock, or suffocation, it may be necessary to give artificial respiration to the victim. There are a number of methods for doing this and you can read about them in a book on first-aid. One of these is the use of an 'iron-lung'. This is a device to produce breathing movements in weak patients or those patients whose chest muscles have been paralyzed.

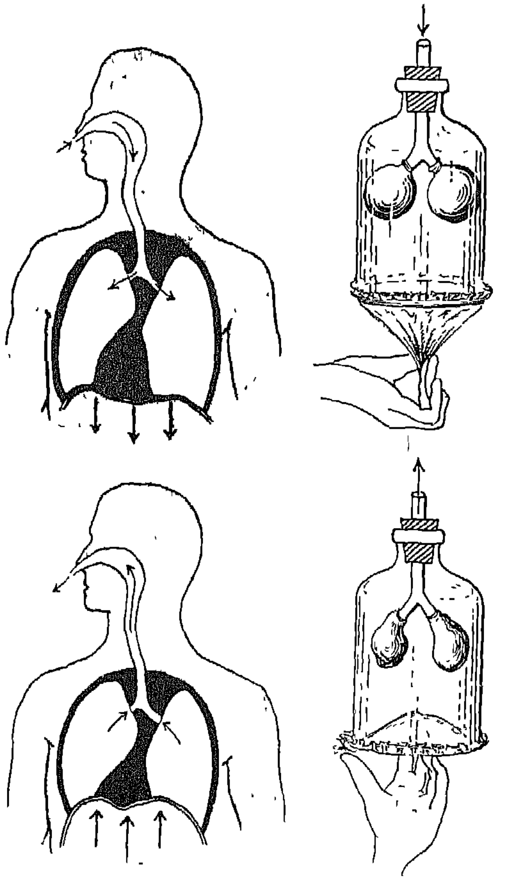


Fig. 28.38. The mechanism of breathing. During inhalation the diaphragm is lowered and the chest cavity expands. This causes the air to be taken into the lungs. During exhalation the diaphragm moves up, the chest cavity becomes smaller and the air is breathed out. The action of diaphragm can be demonstrated in the laboratory by fixing two small balloons inside a bell-jar which is also provided with a rubber diaphragm at the base. The balloons can be made to inflate or collapse simply by pulling or pushing in of the rubber diaphragm.

Excretory System

The excretory organs are primarily a pair of kidneys, a pair of ureters, a urinary bladder and a urethra (Fig. 28.39). The kidneys are located in the abdomen, one on each side of the vertebral column just below the diaphragm. The last two pairs of ribs protect them. The left kidney is usually placed a little higher than the right one. Each kidney is somewhat bean-shaped with a concavity along the inner border. Blood vessels, nerves, lymph ducts and ureters join the kidneys at this point.

The kidneys are made up of a large number of coiled thin-walled tubes called uriniferous tubules, surrounded by a network of blood capillaries (Fig. 28.40). Each tube has a cup-like portion placed towards the outer margin of the kidney. The cup contains a bunch of capillaries from which a large portion of the plasma (along with excretory materials) diffuses into the cavity of the cup. As this plasma flows through the tubular part, the useful material is reabsorbed by the blood while the waste products (like urea, some salts, extra water) pass down into the ureters in the form of urine. The latter is temporarily stored in the urinary bladder. The kidneys not only remove the waste products from the blood but they also play a very important role in maintaining a constant composition of the blood irrespective of what we eat or drink. The lower portion of the urinary bladder forms a tube, the urethra, which opens to the exterior and voids the urine.

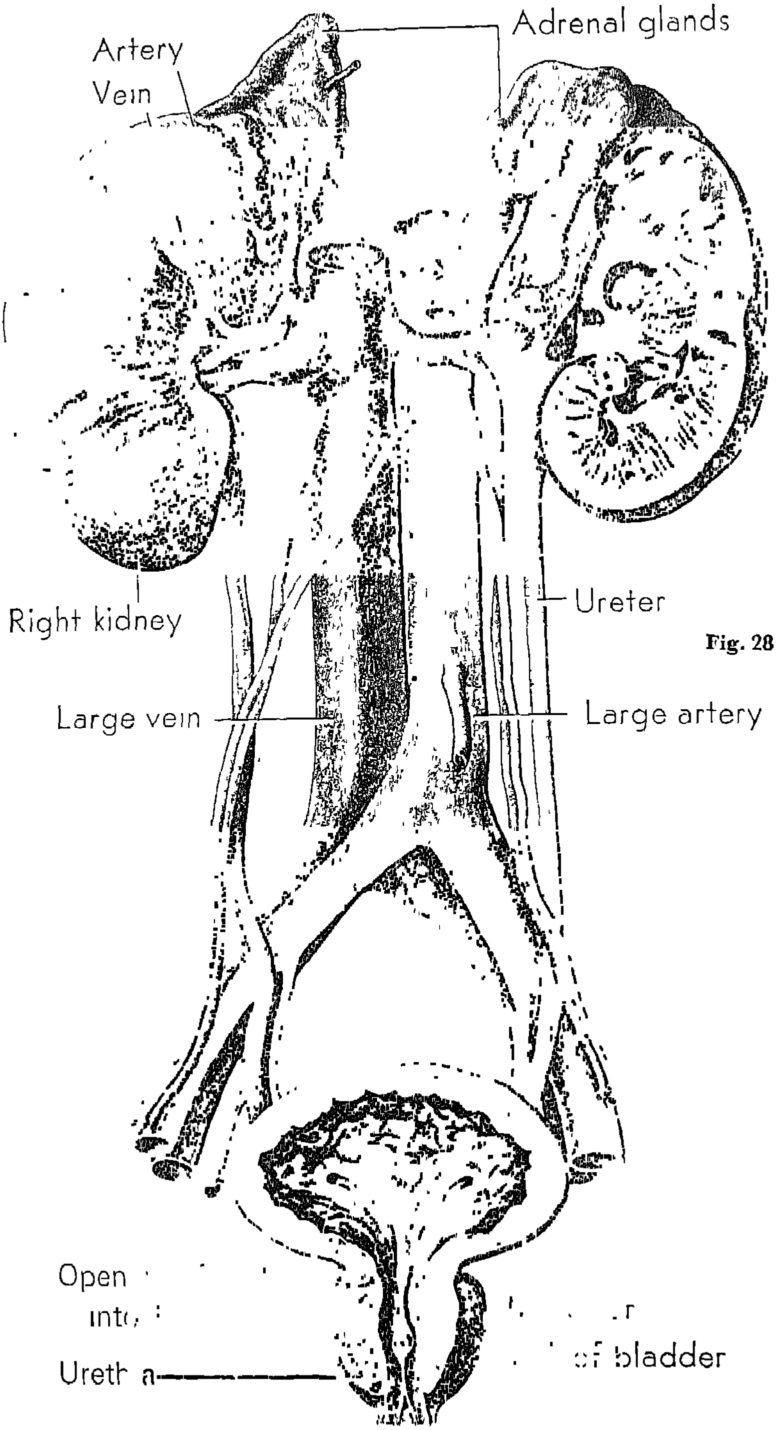


Fig. 28.39. **The excretory organs. The left kidney has been cut open to show the origin of ureter.** From E Kroeber, W.H Wolff and R.L Weaver, *Biology*, D.C. Heath and Company, Boston, 1960.

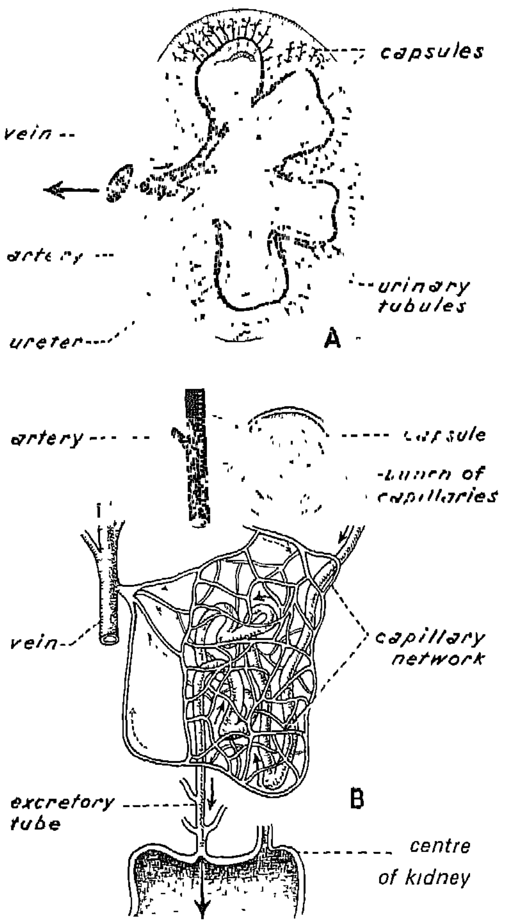


Fig. 28.40. The position (A) and structure (B) of a urinary tubule, the functional unit of the kidney into which the wastes are excreted. The broken arrows show the course of the blood and the solid arrows mark the movement of the excreted wastes. Modified from C.L. Fenton and P.E. Kambly, *Basic Biology*, The Macmillan Company, New York, 1947

Nervous System

All the activities of the body are coordinated by two systems: the nervous and the endocrine. The nervous system is more prompt and consists of the brain, the spinal cord and a network of nerves distributed all over the body. The nervous tissue is made up of nerve cells (*see* page 54). The brain and the spinal cord constitute the central nervous system and their nerves form the peripheral nervous system. A third system, called the autonomous nervous system, controls the activities of the various internal organs without our conscious knowledge or control.

The human brain shows a great advance over that of any other animal in the size of the cerebral hemispheres as well as the quantity of grey matter. In an average adult the brain weighs about 1,350 gm, in a gorilla it weighs 450 gm, and in a dog about 140 gm. The cerebrum is the largest region overlying the other regions of the brain, such as the mid-brain, cerebellum, medulla oblongata, etc. (Fig. 28.41) A deep longitudinal fissure divides the cerebrum into two hemispheres which are held together by a horizontal sheet of fibrous tissue. The surface of the cerebral hemispheres has numerous convolutions. The olfactory lobes are very small and visible only in a ventral view. The centres controlling various functions of the body are shown in figure 28.44.

The medulla oblongata continues below as the spinal cord which runs in the canal of the backbone. Both brain and spinal cord are protected by two tough membranes and the cerebro-spinal fluid which acts as a shock-absorber. There are twelve pairs of nerves arising from the brain and 31 pairs from the spinal cord (Fig. 28.42).

The autonomous nervous system includes the sympathetic and parasympathetic systems. The sympathetic system consists of a double chain of ganglia, one on each side of the spinal cord. Nerve fibres connect these ganglia with the central nervous system and visceral organs. The ganglia of the parasympathetic system are also

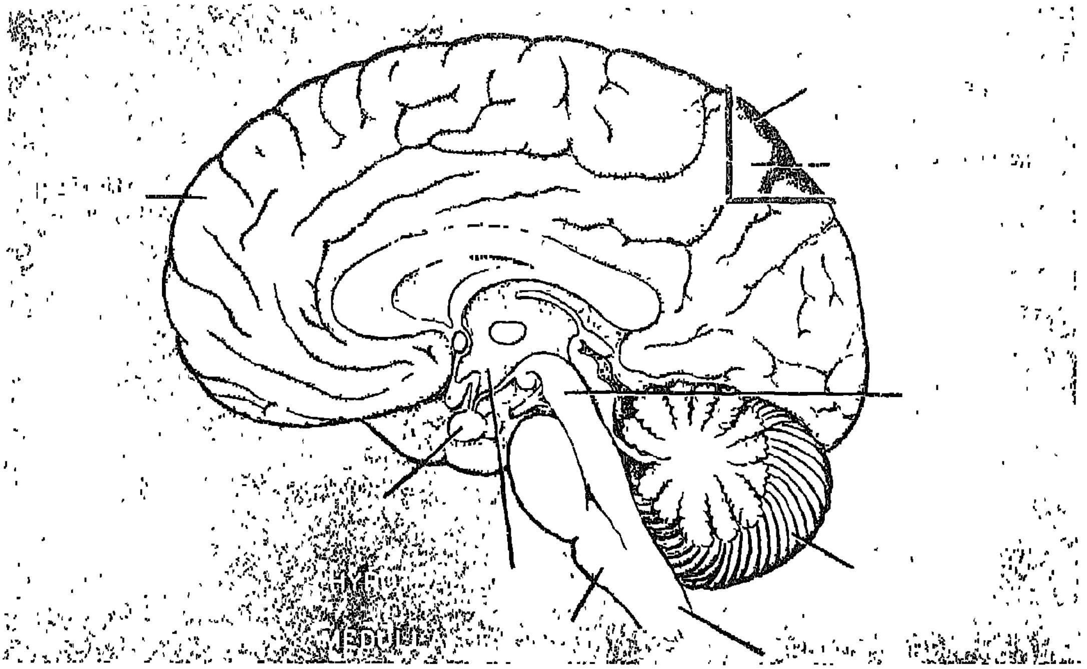


Fig. 28.41. Longitudinal section of the human brain along the line which separates the two halves. The inset shows the location of the cortex and the white matter of the brain. From C Gramet and J. Mandel, *Biology Serving You*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1958

paired but these occur nearer to the visceral organs. This system has its origin in the brain and in the posterior part of the spinal cord. The two systems regulate the functioning of the internal organs such as those of the heart and the intestinal wall (Fig 28 43) The sympathetic system usually speeds up the action of a particular organ and the parasympathetic system slows it down

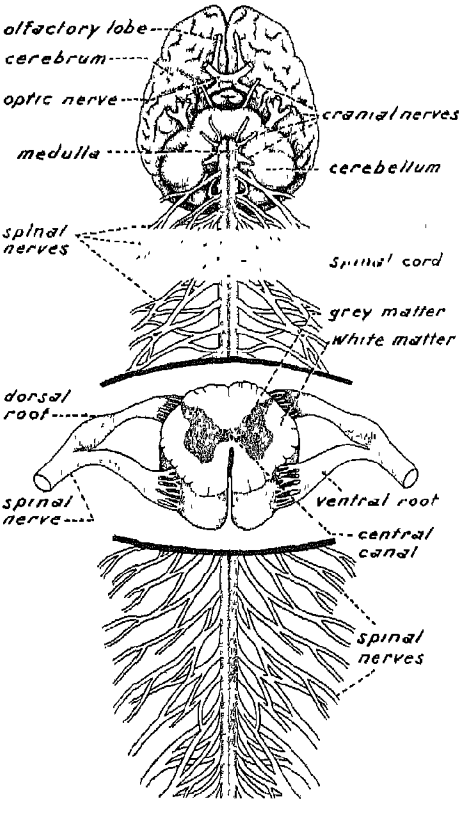


Fig. 28.42. The human nervous system as seen from the underside of the brain. In all there are 12 pairs of cranial nerves and 31 pairs of spinal nerves. The inset shows the spinal cord in section. After C. Gramet and J Mandel, *Biology Serving You*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1958.

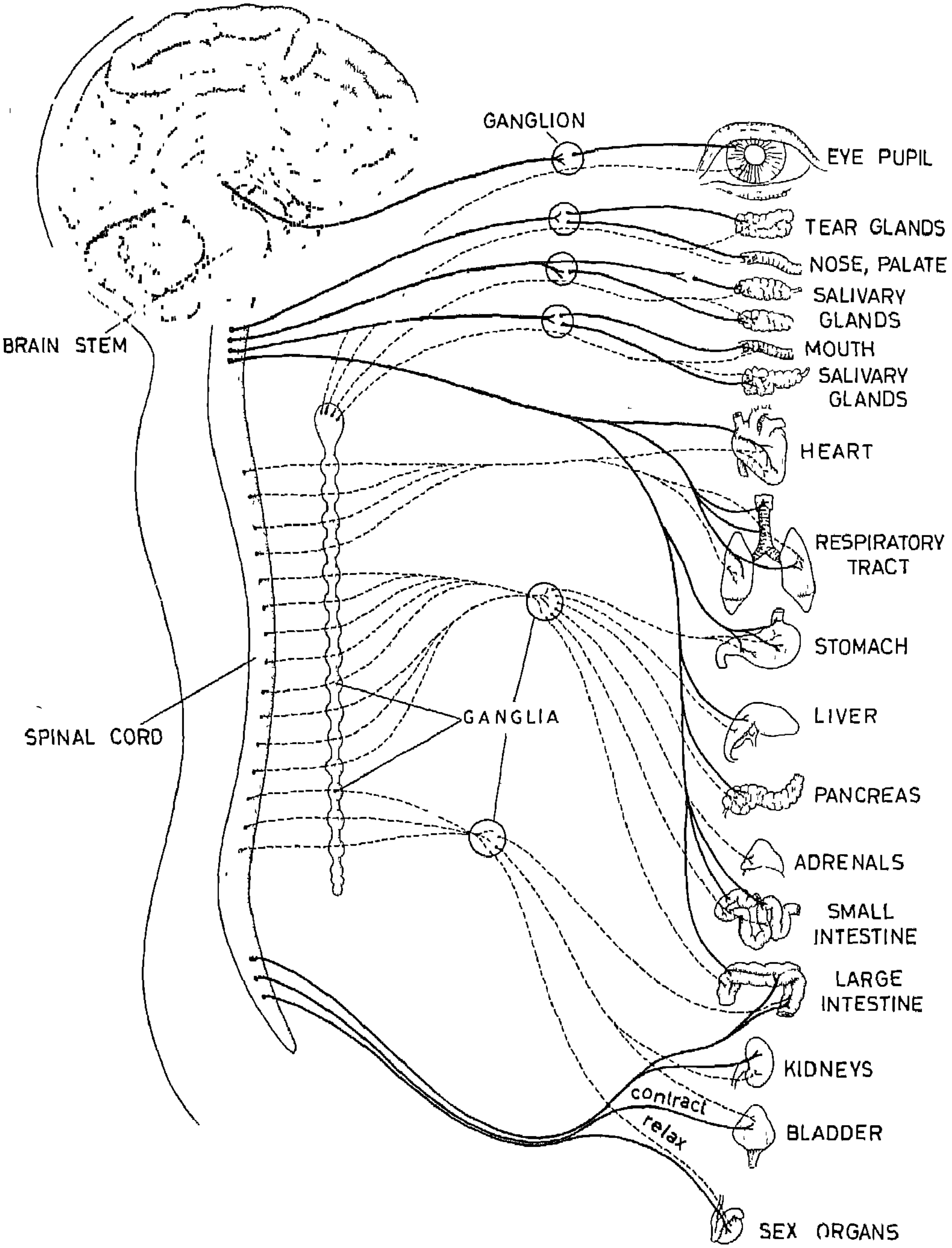


Fig. 28.43. **The sympathetic (broken lines) and parasympathetic (solid lines) divisions of the autonomous nervous system in relation to the central nervous system (brain and spinal cord) and the various organs controlled by them. Note the chain of ganglia of the sympathetic division along the spinal cord.** From various sources.

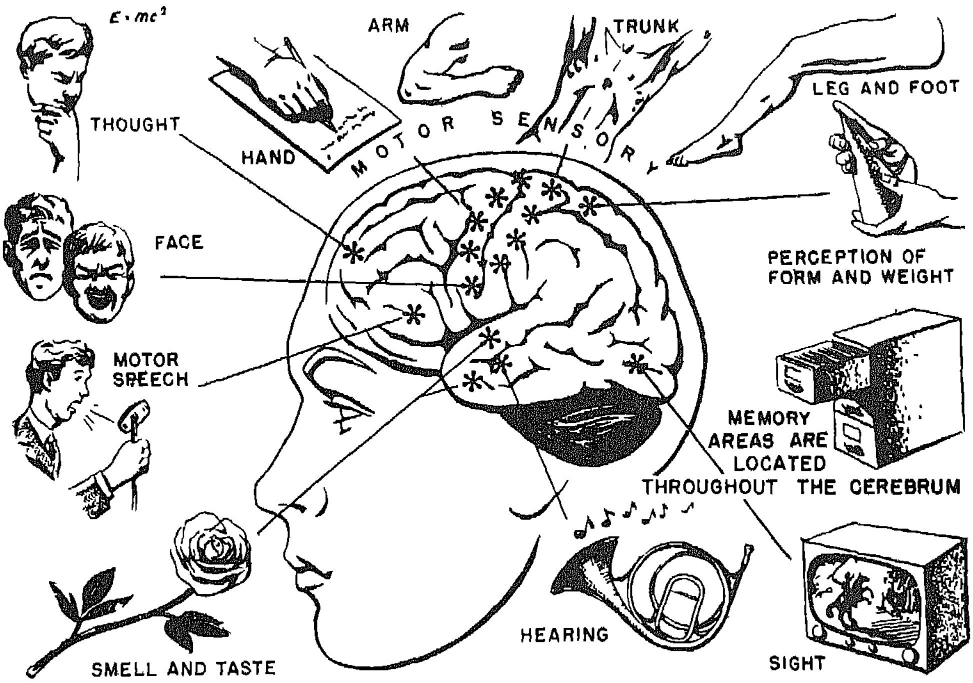


Fig. 28.44. Human cerebral functions. A large part of the cerebrum is made up of association areas that are believed to be centres for memories and for intelligence. From C. Gramet and J Mandel *Biology Serving You,* Prentice-Hall, Inc, Englewood Cliffs, New Jersey, 1958.

Sense Organs

Our five usual senses are those of vision, hearing, smell, taste and touch. These are carried out through the eyes, ears, nose, tongue and skin respectively The skin also feels pressure, pain, cold and warmth.

The eye. The eyes are somewhat ball-like and are lodged in the deep skull cavities (orbits). The eyelids can rapidly close to prevent dust or other things from entering the eyes. The eyelashes also help in this function On any irritation, due to a fallen particle or due to a gas or smoke, or under certain emotions, the eyes are flooded with a watery secretion or tears. This secretion comes from the tear glands located near the outer border of each eye and it is poured through minute ducts on the inner surface of the upper eyelid (Fig. 28.45) Movement of the upper eyelid spreads the secretion over the eye to wash off any dirt.

The wall of each eye is made of the same three concentric layers (sclerotic, choroid and retina) seen in the frog. In the front the sclerotic layer forms a transparent, somewhat bulging, circular cornea. The cornea can be stored and grafted on to another person The cornea and the rest of the exposed sclerotic layer are covered by another very thin transparent membrane, the conjunctiva, which is the continuation of the inner surface of the eyelids. The pigmented iris, formed by the middle or choroid layer encloses the pupil, visible from outside as a dark window. The iris

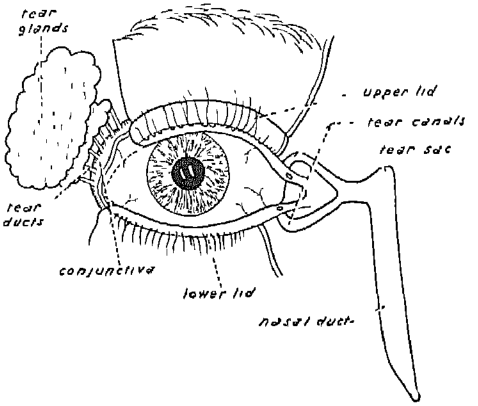


Fig. 28.45. The right eye together with tear glands. Our eyes are always somewhat wet and become flooded with a watery secretion or tears under certain emotional conditions or due to smoke or gas. After W. W. Tuttle and B. A. Schottelius *Textbook of Physiology*, The C. V. Mosby Company, Saint Louis, 1965

consists of delicate muscles which regulate the size of the pupil and consequently control the amount of light passing to the retina. Just behind the pupil lies a biconvex lens which is held in position by ligaments and muscles. A transparent watery fluid (aqueous humour) fills the narrow space between the lens and the cornea (Fig. 28.46A). The large chamber behind the lens is filled with a clear, gelatinous substance (vitreous humour).

The sensory layer, called retina, consists of two types of cells, the rods and cones (Fig. 28.46B). The rods are sensitive to dim light and do not distinguish colours. The cone cells are sensitive to bright light and can distinguish colours. The cone cells are most numerous near the back of the eye opposite the pupil. This part is somewhat depressed and is known as the **yellow spot** or **fovea.** Vision is the sharpest here. The sensory fibres from the retina bundle together and emerge from the back of the eyeball as the optic nerve.

At the exit of the optic nerve there are no rods or cones. The part of the image falling at this place is not perceived, and so this place is called the **blind spot**. You can demonstrate its existence by a simple experiment. Take a sheet of paper and put two marks, about six centimetres apart along a horizontal line. Hold the sheet in front of your eyes at a distance of about 20 cm. Now close your left eye and gaze at the left mark with your right eye. While doing this you can still feel the presence of the other mark. Keep looking at the left sign and gently move the sheet towards your face. A position will be reached when the right mark vanishes. It will reappear if you bring the sheet closer still. Repeat the process with the left eye, this time gazing at the sign of the right side. In each case, when the sign disappears, the image of that sign is falling on the blind spot of your eye.

A normal eye can focus the image of both distant and nearby objects over the retina (Fig. 28.46 C). This is possible by a process called **accommodation** and is achieved by changing the convexity of the lens (Fig. 28.46 D). Focussing at the nearby objects involves contraction of the muscles which increases the convexity of the lens. Hence looking continuously for a long time at near objects, such as while reading a book, may cause strain and fatigue in the eye.

Common defects of the eye. Near-sightedness occurs when the image of a distant object is focussed in front of the retina. This may be due to lengthening of the eyeball from front to back or may be due to increased convexity of the lens. It can be corrected by using appropriate concave glasses. **Far-sightedness** is due to just the opposite conditions. It can be corrected by wearing suitable convex lenses. **Astigmatism** is due to irregularities in the shape of the lens and the cornea. Cylindrical

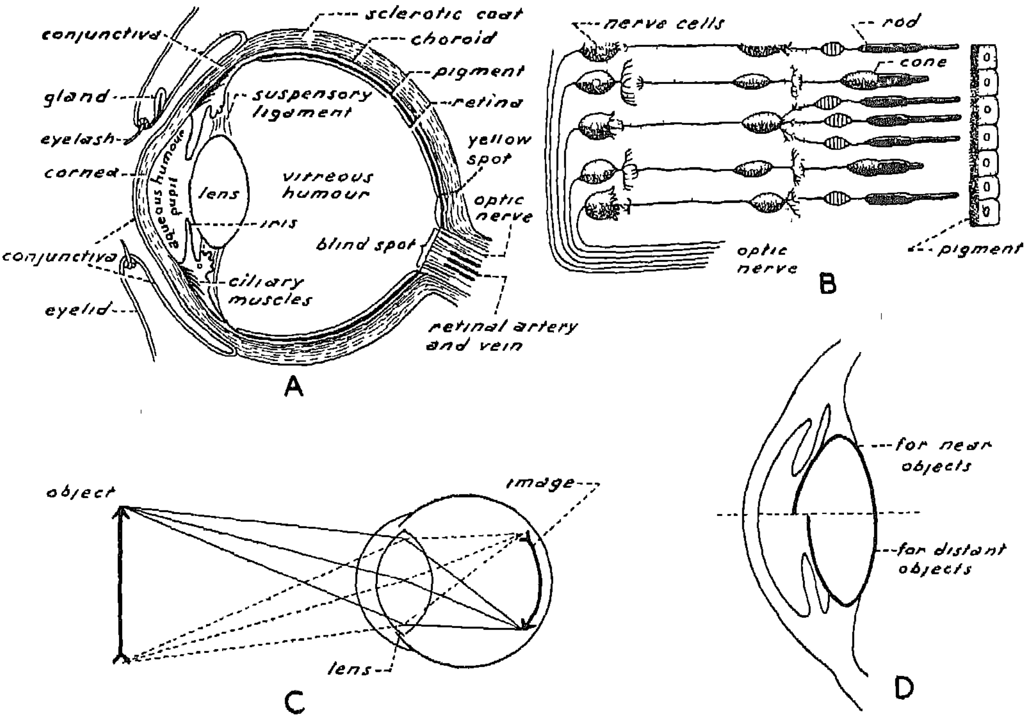


Fig. 28.46. The human eye. A. Median vertical section. B. A small part of the retina enlarged to show the nerves, rods, cones and pigment cells. C. The lens serves to form an image (reduced and inverted) on the retina in the same way as a camera lens produces an image on the photographic film. D. Changes in the shape of the lens to focus the near and distant objects (accommodation). From T I Storer and R.L. Usinger, *General Zoology*, McGraw-Hill Book Company, Inc , New York, 1957.

glasses are used to correct this defect. Old-age sight is due to loss of flexibility of the lens, and one feels difficulty in focussing at nearer objects. This defect starts appearing from the age of about forty to forty-six years. It is corrected by the use of convex lenses (Fig. 28.47). In **cataract** the lens becomes opaque due to a variety of causes. Its treatment calls for the services of an eye specialist

Care of the eyes. Do not strain your eyes by reading in poor light. You should also avoid bright light that shines directly into your eyes. Closing tired eyes or looking into off space for a moment gives them rest and relief. Eyes should be washed at least twice daily. Whenever you feel any trouble in the eyes consult your doctor; you may have to use spectacles if there is difficulty in seeing.

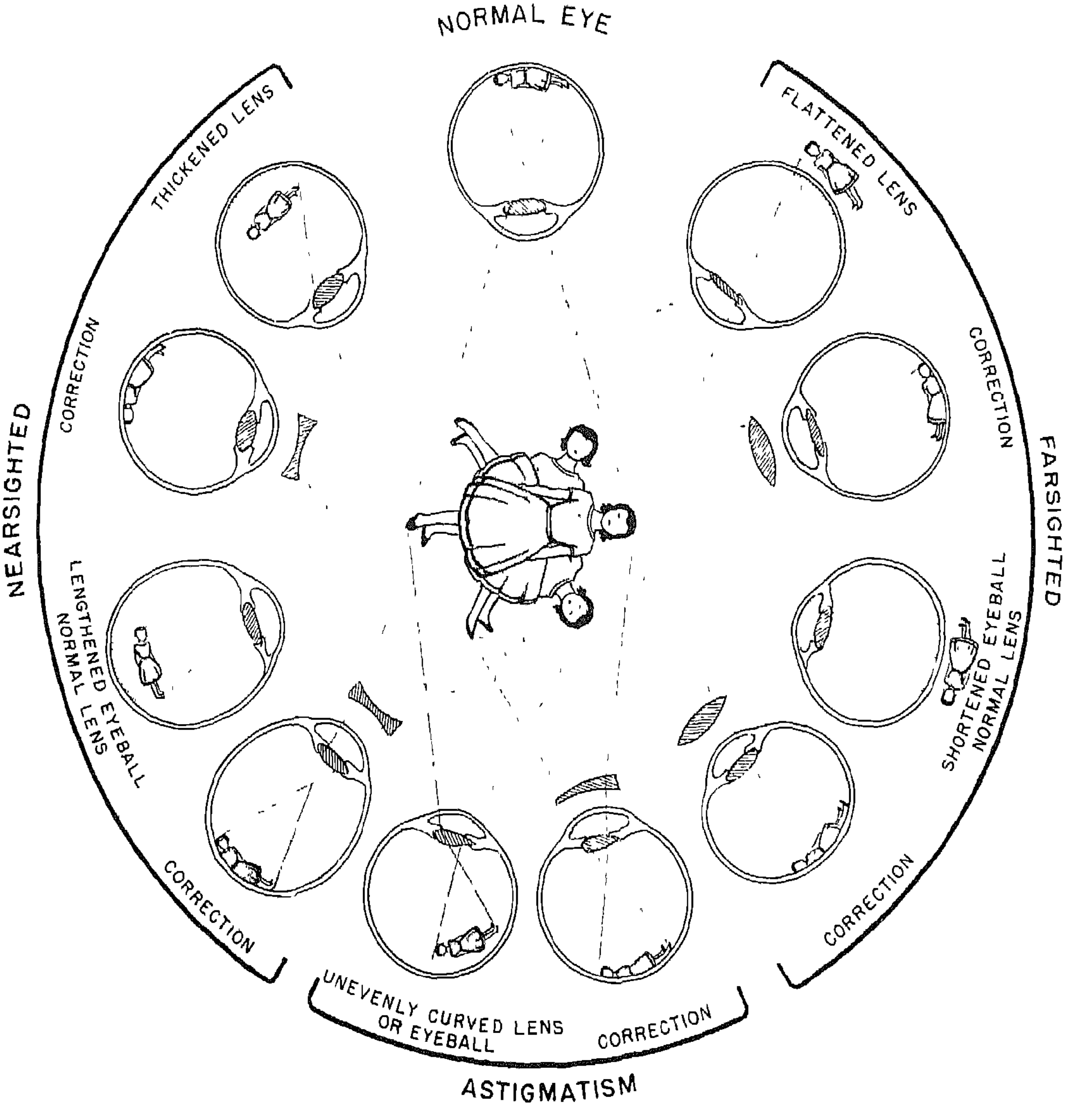


Fig. 28.47. Some common defects of the eye. From C Gramet and J. Mandel, *Biology Serving You*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1958

The ear. The ear consists of three parts—the external, the middle, and the internal (Fig. 28 48). The external or the outermost, projecting part of the ear is a skin-covered cartilaginous organ called **pinna.** It collects sound waves and admits them into the tubular auditory passage. Some animals can move their external ears

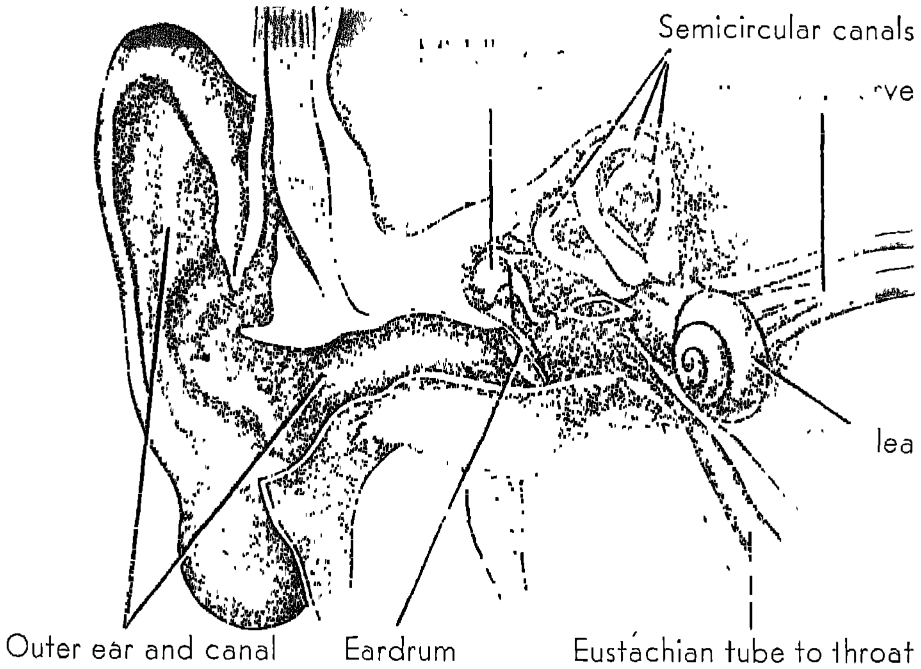


Fig. 28.48. Sectional diagram of the human ear. Note the demarcation into the external ear, the middle ear and the internal ear. Courtesy of the Sonotone Corporation, New York

in the direction of sound, but such muscles are vestigial in man although some people do have the capacity to move their ears slightly. A waxy layer in the auditory passage entangles the bacteria and any other minute organisms that may creep in. Similarly, the fine hairs at the outer opening also have a protective function. Somewhat obliquely placed at the inner end of the auditory passage is a delicate blue-grey membrane called the **eardrum.**

The middle ear consists of a set of three tiny bones which are lodged in a chamber. The first bone is the **hammer** attached to the inner surface of the eardrum. Next is the **anvil**, and the third is the **stirrup.** The inner end of the stirrup fits into an oval opening in the inner wall of the chamber. An air passage, the **eustachian tube**, connects the floor of the middle ear with the pharynx. It balances the air pressure on either side of the eardrum.

The internal ear is very delicate. It has two main regions—the upper **utriculus** and the lower **sacculus.** The upper portion is connected with three semicircular canals which are concerned with the sense of position of the body and not with hearing. From the sacculus arises a long tubular part or **cochlea**, which is coiled like a conch shell and is imbedded in a bone of the skull. It carries a system of canals and spaces which are filled with lymph-like fluids, and there are fine sensitive membranes running across it. Branches from the auditory nerve enter these membranes. This part is concerned with the sense of hearing (Fig. 28.49).

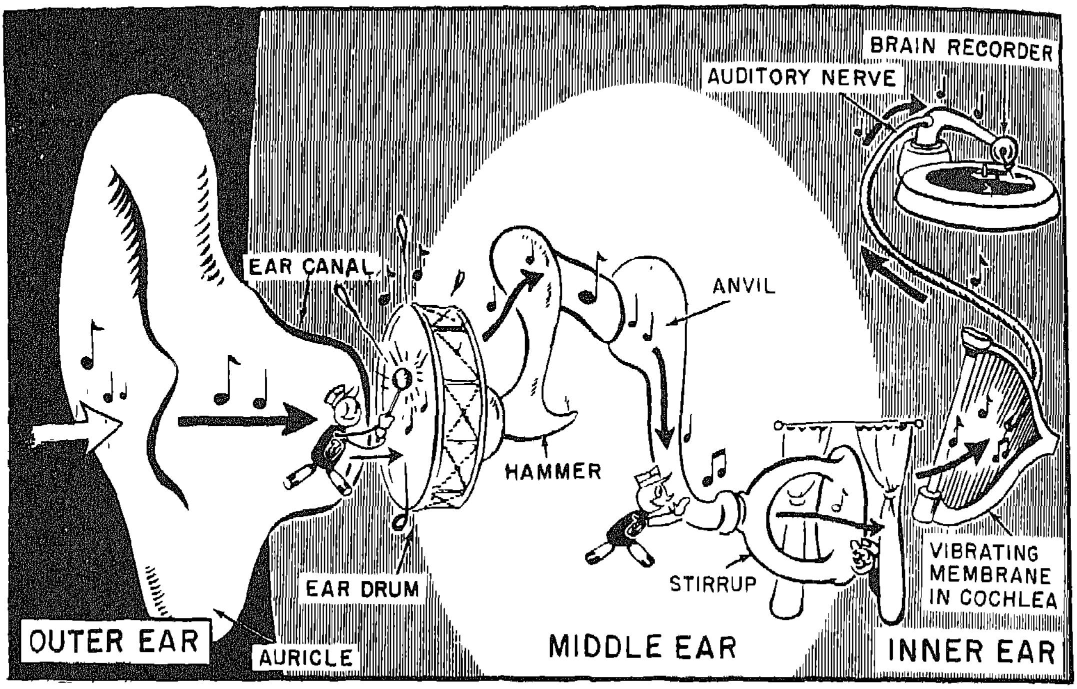


Fig. 28.49. The mechanism of hearing. Compare this cartoon of the ear with the diagram of the actual parts to explain how we hear. Courtesy of the Sonotone Corporation, New York.

The nose. The cells for the perception of smell are situated in the lining of the nasal chambers The nerve fibres from these cells run through the bones and reach the smell region of the brain. The smell-carrying particles from a substance, such as a rose, enter the nose with the air and stimulate the sensory cells

The tongue. The surface of the tongue carries a large number of **taste buds** each of which is composed of a cluster of large

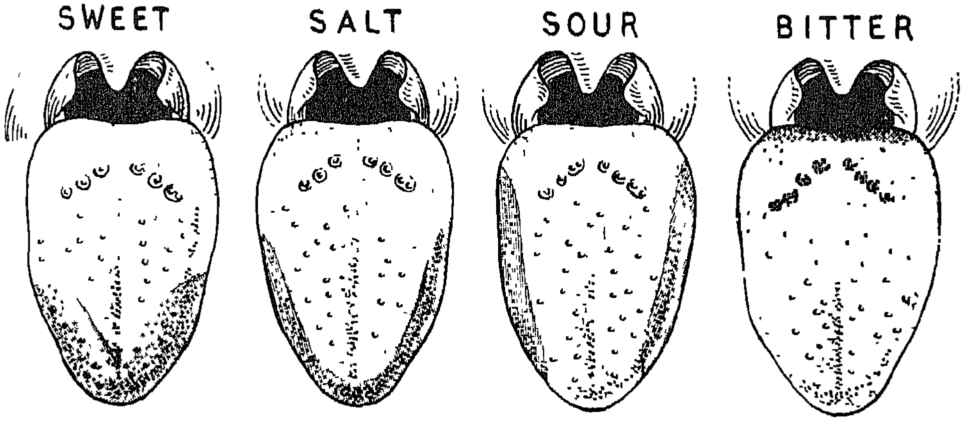


Fig. 28.50. Diagram showing the distribution of the different kinds of taste buds on the tongue (shaded areas).

ciliated cells lying in a small depression of the surface. Sensory nerve fibres arise from the inner ends of the sensory cells and form the taste nerve. Food mixed with saliva enters the pores of the taste buds and stimulates the hair-like nerve endings which give us the sense of taste. Taste buds receptive to each of the basic four tastes—bitter, sour, salt and sweet—are shown in figure 28.50.

The skin. The skin can perceive five types of sensations—heat, cold, touch, pain and pressure. The organs for these sensations are distributed irregularly all over the skin. The minute projections on the surface of the palm along the lines, which you can easily see with a magnifying glass or even with unaided eyes, carry such touch-sensitive cells placed deeper in the skin. Similarly, there are separate sensory cells for heat and cold.

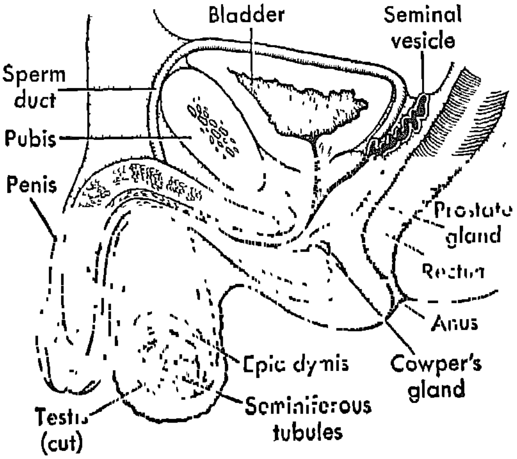


Fig. 28.51. The male reproductive organs and the associated structures viewed as if cut along the midline of the body. From G G Simpson, C S Pittendrigh and L H Tiffany, *Life: An Introduction to Biology*, Harcourt, Brace and Company, Inc , New York, 1957

Reproductive System

The essential male reproductive organs are a pair of **testes** lodged in **scrotum** outside the body (Fig. 28.51). Numerous fine ducts convey sperms from each testis to a highly convoluted collecting tube which, together with the previous ducts, forms a kind of knot, the **epididymis**, attached to the testis. The two collecting tubes continue as a pair of **sperm ducts** which open into a pair of **seminal vesicles** located behind the bladder. The two ejaculatory ducts arising from the seminal vesicles join the **urethra** which opens to the outside at the tip of the penis. The urethra also carries the urine. The penis is the copulatory organ for the transfer of the sperms to the female reproductive tract. It is a highly muscular organ richly supplied with large vascular spaces which when filled with blood make the penis erect. The prostate gland and Cowper's gland, open in the urethra. Their viscous secretion serves as a medium for the transport of sperms.

The female reproductive organs consist of two small ovaries which lie in the lower part of the abdominal cavity. An oviduct (**fallopian tube**) with a funnel-shaped mouth arises close to each ovary. When the ripe egg is released from the ovary, the funnel picks it up and the fallopian tubes carry it to the pouch-like uterus (Fig. 28.52). Fertilization of the egg occurs in the fallopian tube by one of the spermatozoa that might travel from the vagina up to this region. If fertilized, the descending egg is deposited in the wall of the uterus where it begins to grow into an embryo by repeated segmentation and differentiation of organs. If the egg is unfertilized it soon dies and the superficial mucous layer of the uterus together with some blood is passed as menstrual flow. There is a series of complicated but regular changes in the body during the period between one menstrual flow and the next. This period is called the **menstrual cycle** and is usually repeated within 28 days.

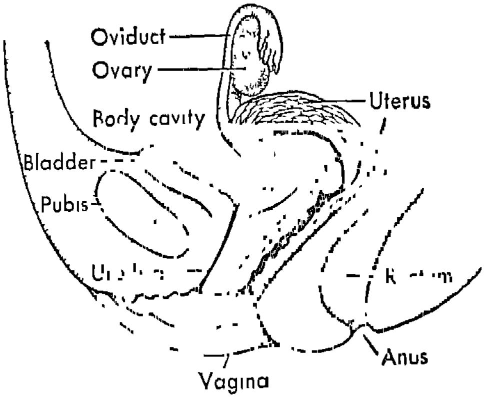


Fig. 28.52. The female reproductive organs and the associated structures viewed as if cut along the midline of the body. From G G Simpson, C S Pittendrigh and L H Tiffany, *Life, An Introduction to Biology*, Harcourt, Brace and Company, Inc., New York, 1957.

Endocrine Glands

You have read in Chapter 25 that the frog has a number of endocrine (ductless) glands, whose secretions (hormones) affect the body in very remarkable ways. Many of these glands are represented throughout the vertebrate series, including man. The role of endocrine glands in man has been extensively studied in recent years, and **endocrinology** has become an important discipline in animal physiology Figure 28 53 shows the various endocrine glands in the body. The **thyroid gland** is a two-lobed structure lying ventral to the windpipe in the neck region. Its secretion, thyroxin, can even be produced artificially. This hormone regulates the rate of metabolism. The gland becomes more active during rapid growth and development and in pregnant women. It is more active in winter, because then it has to speed up oxidation and keep the body warm. Overactivity of

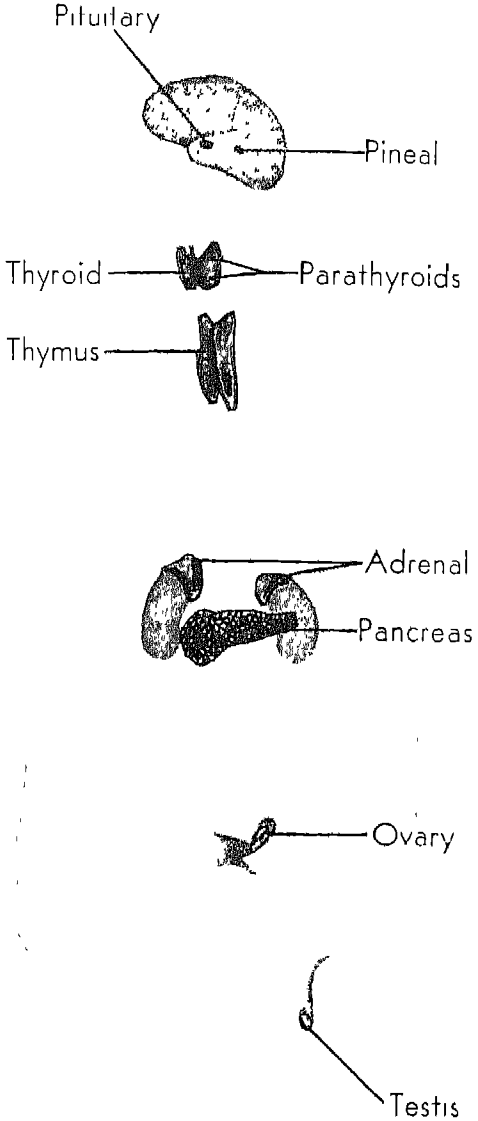


Fig. 28.53. The location of the various endocrine glands. From E Kroeber, W.H. Wolff and R L. Weaver, *Biology*, D.C Heath & Co, Boston, 1960.

the gland causes speeding up of the rate of heart beat, increased restlessness and often a protrusion of the eyeballs. It can occasionally be cured by rest, but the direct method is to surgically remove a part of the gland. Underactivity of the thyroid gland produces the opposite symptoms leading to physical and mental retardation

Sometimes people suffer from simple **goitre** (a swelling in the neck due to overgrowth of the thyroid). This is due to deficiency of iodine which is normally a rich constituent of thyroxin The gland grows larger in order to produce more thyroxin to meet the requirement of the body. People eating saltwater fish and other food of marine origin rarely have goitre, because seawater is rich in iodine. In certain districts the soil may be deficient in iodine and thus there may be frequent cases of simple goitre However, the addition of iodine compounds to table salt and to the water supply has largely prevented this disease

The **parathyroids** are four small glands, two on each side of the dorsal surface of the thyroid. Their secretion controls the use of calcium in the body and thereby affects the growth of bones, contraction of muscles, and nervous activity.

The **thymus** is located under the breast bone and extends above into the neck. It is best developed during childhood, and shrinks to a very small size in the adults. Its exact function is yet unknown.

The **Islets of Langerhans** are special groups of cells in the pancreas Their secretion, **insulin**, regulates the storage of sugar in the liver. You would recall that one of the main functions of liver is to convert excess of sugar into glycogen and store it for future use. This can happen properly only under the influence of insulin. This hormone also regulates the oxidation of sugar in the tissues In short, insulin controls the sugar metabolism

You would have heard of people suffering from diabetes (more correctly called **diabetes mellitus**). This disease is characterized by the presence of excessive sugar in the blood and ultimately in the urine. It results from the failure of production of insulin. In 1922, two famous Canadian physiologists, Banting and Best, developed a method of isolating insulin from the pancreas of slaughtered animals, and demonstrated its action in giving relief to diabetic patients There are well-established cases of some diabetic patients who have lived normally for as long as 40 years by taking injections of insulin

The **adrenal glands** are a pair of cap-like bodies lying on the top of the kidneys, and hence they are also called suprarenals They have two regions—an outer cortex and an inner medulla. The cortex secretes a variety of hormones which regulate certain phases in the metabolism of carbohydrates, fats and proteins. They also regulate the salt and water balance. **Cortisone**, one of the cortical hormones, is used in treating rheumatoid arthritis. When the cortical secretions are absent or reduced, a serious disease results. The medulla secretes **epinephrine** (or **adrenalin**) which regulates blood pressure and other activities controlled by the sympathetic nervous system. This hormone prepares the individual for meeting emergency situations. During emotional stress, more of this is produced resulting in an increase in blood pressure, rapid and stronger heart beat, and release of more sugar from the liver into the blood to provide material for increased oxidation and dilation of the eye pupil. The extra vigour, which you put in to win a race in its final moments, is again an effect of adrenalin, The **pituitary gland** is about the size of a large pea seed, weighing nearly half a gram, and is attached by a stalk to the lower part of the brain. It has three regions called the anterior, intermediate, and posterior lobes The anterior lobe secretes several hormones Five of these activate other endocrine glands (thyroid, adrenal and gonads). For this reason the pituitary is called the master of the endocrine system The other glands in turn regulate the activity of the anterior lobe. Thus, excessive production of thyroxin may slow down the production of the corresponding thyroid-stimulating hormone An excessive production of the pituitary hormone leads to gigantism, and its deficiency causes dwarfs or cretins If there is any over secretion of the pituitary in an adult, it leads to **acromegaly** (disproportionate enlargement of certain bones, specially those of jaws, nose, hands and fingers) In mothers, the secretion of milk is stimulated by **prolactin.**

The intermediate lobe of the pituitary produces a hormone which stimulates formation of pigment in skin

The posterior lobe secretes two important hormones One of these helps in increasing the absorption of water from the kidney tubules. A deficiency of this hormone leads to **diabetes insipidus** (removal of too much of water from the body, more frequent urination, and excessive thirst). The other hormone regulates contraction of the smooth muscles specially those of uterus in child birth.

The interstitial cells of the testes, i.e those cells which lie between the sperm producing tubules secrete the male hormone It brings about characteristic changes at the time of attaining adolescence or puberty. Boys begin to grow hair on the face and in other regions of body, their voice deepens

The ovaries secrete the female hormone. This produces the characteristic changes when the girls attain puberty, such as the development of breasts, broadening of hips, and onset of menstruation, etc With the discharge of a ripe egg the ovary also releases the female hormone into the body cavity This causes the uterine walls to thicken and thus prepare them to receive the fertilized egg Meanwhile the follicle cells of the ovary, where the previous egg had discharged, form a yellowish mass of cells, the **corpus luteum.** It produces another hormone, called **progesterone**, which continues to prepare the uterus to receive the egg If the egg is not fertilized, the corpus luteum begins to degenerate and with the menstrual flow the uterine wall returns to normal. The cycle is repeated in about four weeks Another follicle develops under stimulation from the follicle-stimulating hormone of pituitary and the whole chain of events is repeated. If the egg is fertilized, it becomes implanted in the uterine wall. In that case the corpus luteum continues to secrete progesterone and further menstruation stops. Simultaneously, the mammary glands enlarge and other necessary changes are brought about in the body.

SUMMARY

The mammals include such familiar animals as rabbit, dog, cow, horse, bat, lion, monkey and man himself. The important features of this group are the presence of hairs, external ears, a neck formed of seven vertebrae, and teeth set in sockets. The young are nourished by the milk produced in the mammary glands of the female The mammals inhabit a large number of different habitats Some of the common orders are

(1) Monotremata or egg-laying mammals such as the duckbill and the spiny ant-eater, natives of Australia; (2) Marsupialia or pouched mammals, such as the kangaroo, characterized by the presence of a pouch or marsupium into which the young ones are reared before they are able to move about freely; (3) Insectivora or insect-eating animals of which hedge-hogs, moles and shrews are the commonest examples, (4) Edentata or toothless animals such as the scaly ant-eater and armadillo in which the body is covered with horny plates or scales intermixed with hairs, (5) Rodentia or gnawing mammals lacking canine teeth but having very sharp incisors, e g rabbit, hare and porcupine, (6) Ungulata or hoofed mammals such as horse, ass, zebra and rhinoceros (all having an odd number of toes) and cow, deer and camel (having even number of toes); (7) Proboscidea or trunk-bearing forms which are the largest present day land animals, namely, the elephants; (8) Chiroptera, the only mammals that have taken to the flying habit such as bats, (9) Carnivora or mammals with powerful claws and canine teeth including such forms as lion, tiger, fox, jackal, cat and seal; (10) Cetacea or fish-like mammals that are aquatic forms and in which the external ears and hairs are present only in the embryos, include dolphins, porpoises and whales; and (11) Primates or mammals with superior brains such as the monkeys, lemurs, apes and man, all of which possess hands which can be used to grasp the objects The four man-like apes living at present are the gibbon, orang-utan, gorilla and chimpanzee

There is only a single living species of man, namely, *Homo sapiens* although in the remote past several other species also existed The human organism is the most highly evolved creature possessing the power of speech, the highest intelligence, and the capacity to work with tools or machines

The skin covers and protects the body and synthesizes vitamin D in the presence of sunlight It is composed of a superficial layer of cells (the epidermis) overlying the inner region (the dermis) containing blood vessels, nerve fibres and glands. The hairs represent special outgrowths of the epidermis The colour of the skin and hairs is due to the presence of melanin

The basic plan of the human skeleton is the same as in other vertebrates However, because of the erect posture, the hip girdles have become modified to support the abdominal organs

The digestive tract of man is nearly nine metres long and consists of the mouth, oesophagus, stomach, small intestine and large intestine. The tract is associated with several digestive glands: salivary glands, the gastric and intestinal glands lining the stomach and intestine, and the liver and pancreas. The process of digestion is initiated in the mouth itself; it continues in the stomach and is completed in the small intestine. The food is converted into soluble form, absorbed into the blood and lymph, and distributed to all parts of the body. The undigested food collects in the large intestine where it loses much of its water and becomes thicker in consistency It is eliminated as faeces

The blood carries food and oxygen to all parts of the body It has two distinct parts—the straw-coloured plasma, the red and white corpuscles and the platelets The mature red corpuscles lack nuclei. The blood circulates to all parts of the body through two types of blood vessels, the arteries and veins The heart beats nearly 75 times a minute and acts as a pump. It is made of two halves separated by a wall Each half consists of a receiving chamber, the auricle, and a muscular pumping chamber, the ventricle. Each auricle maintains continuity with the ventricle of its side through a small opening. The blood from the body comes into the right auricle and is pumped by the right ventricle into the lungs where it is oxygenated. From here the blood returns through the pulmonary vein into the left auricle and fills the left ventricle which then pumps it back to the body through the dorsal aorta This vessel gives off branches to the various parts of the body. The blood passes through smaller and smaller arteries and finally comes into the veins through the capillaries Depending on the presence or absence of specific proteins in the blood, four blood groups are recognized For successful blood transfusion a knowledge of the blood groups is absolutely essential The continuous loss of blood from cuts or bruises is prevented due to clotting.

The lymph is a colourless or yellowish liquid that oozes out of the capillaries and bathes all the tissues. It flows in lymph vessels distributed all over the body. It finally enters the veins to become a part of the blood once again. The spleen stores blood which is released whenever there is loss due to haemorrhage. The liver is an important organ controlling many functions in the body.

The respiratory system includes lungs and an air tube or trachea leading from the pharynx to the lungs. The lungs are richly supplied with blood capillaries. The gaseous exchange occurs through the thin membranes lining the small cavities or alveoli in the lungs, During inhalation the diaphragm is lowered and the chest is raised, so that the air rushes into the lungs through the nostrils During exhalation the diaphragm and chest come back to their normal position and the impure air is pushed out.

The waste materials of the body are removed by the skin and urinary system. The latter comprises a pair of kidneys, ureters, urinary bladder and urethra. The non-proteinaceous nitrogenous wastes from different organs pass into the blood when it enters the kidney through the renal artery and the waste material contained in it is filtered by the numerous urinary tubules The ureters carry the urine into the urinary bladder from where it is excreted periodically The blood, free of these wastes leaves the kidney through the renal vein.

The nervous and endocrine systems control the activities of the body The nervous system consists of the central, peripheral and autonomous divisions The brain and spinal cord form the central nervous system, and the cranial and spinal nerves constitute the peripheral nervous system. The autonomous system is formed by the sympathetic and parasympathetic nerves. The peripheral nerves conduct impulses to and from the central nervous system The brain with its large cerebrum is mainly concerned with thinking. The spinal cord acts as a reflex centre and as a conductor of impulses.

The male reproductive system consists of the testes and the associated ducts for conducting the sperms. The sperm ducts join the urethra which opens at the tip of the penis. The prostate gland and Cowper's gland secrete fluids in which the sperms are suspended.

The female reproductive system consists of the ovaries, oviducts, uterus and vagina. The ovaries release one egg every month. The egg is fertilized in the oviduct and develops into a baby in the uterus. Before birth, the baby is nourished in the mother's womb If fertilization does not occur, the egg degenerates and is eliminated in the menstrual flow

The endocrine glands control the growth and behaviour of the body by means of their secretions which are collectively termed hormones. They pour their secretions directly into the blood flowing through them.

QUESTIONS

1. What are the most important distinguishing characters of mammals?
2. Why does your skin become dry during winter and greasy during the hot and rainy season?
3. What is the utility of the ribs in your body?
4. Enumerate the chief functions of the liver.
5. What is the difference between blood and lymph?
6. How many different senses does your skin perceive?
7. What are the peculiarities of the animal known as duckbill? How do you justify its inclusion in the mammals?
8. How do bats manage to avoid collisions against objects in the dark?
9. Mention some similarities between man and chimpanzee.
10. How is the human circulatory system more advanced than that of frog?
11. Name the artery that does not carry pure blood and the vein which carries pure blood.
12. Breathing through the mouth is said to be less healthful than through nose Why?
13. What is the difference between breathing and respiration? What causes coughing?
14. Why does it become difficult to breathe at high altitudes?
15. How do you account for the fact that blood starts oozing at almost any place in the body if it is pricked with a needle? How does the blood clot?
16. People often speak in terms of winning or breaking somebody's heart From your knowledge of the human heart do you think these statements have any relevance?
17. How do you know that a whale is not a fish and a bat is not a bird?
18. Account for the following
    a. The largest animals (whales) live in water whereas the largest trees live on land.
    b. The wound made by a leech keeps bleeding for a long time whereas that made with a knife stops bleeding after some time.

19 What is a marsupial? Give two examples

20. Supposing one of your classfellows insists that whales and dolphins are fishes. How will you convince him of their being mammals?

21. The bile does not contain any enzyme, yet it is essential for normal digestion. Explain.

22 A post-mortem study often involves an analysis of liver Explain the importance of this test

23 How does the urinary system of man differ from that of frog?

24. Supposing you had a breakfast consisting of bread, butter, egg and milk. Trace the fate of the nutrients contained in them as they pass through the various parts of the alimentary canal

25 Which is superior—a strictly vegetarian diet or a mixed diet? Why?

26. What is the advantage of having villi in the intestinal wall?

27 The wall of the alimentary canal has a thick layer of muscles. What is the function of these muscles?

28. The brain of an elephant is much heavier than that of a man. Explain why the former is not as intelligent as man.

29 Why is there almost no absorption of food in the stomach?

30. Justify the statement. We really see and hear with our brain and not with eyes and ears alone

31 How are the hands of man unique as compared to those of most other mammals?

32. Give six examples of the body functions which are under the control of autonomous nervous system

33 Supposing you discovered a new ductless gland in an animal's body. How would you go about testing its function?

34. Which blood vessel connected to a ductless gland carries the hormone—a vein or an artery?

35. By means of a simple diagram show what happens when someone pricks your hand with a needle

36 Trace the path of a drop of blood in your little finger to the heart and lungs and back again.

37. Trace the changes in the contents of the blood as it flows through various parts of the body including the ductless glands

38. What is meant by blood transfusion? What part of the blood is used for this purpose?

39. How does exercise help in the proper circulation of blood?

40. How do the horns of cattle, rhinoceros, giraffe and deer differ from one another?

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CHAPTER 29

Protozoa— The Single-Celled Animals

THE phylum Protozoa includes unicellular animals in which the single cell carries on all the essential processes of life such as locomotion, feeding, digestion, egestion, respiration, excretion and reproduction. In a few species the protozoa have established a colonial existence. In such instances, the individual 'animals' have specialized in such tasks as locomotion and reproduction.

Locomotion in protozoa takes place by means of protoplasmic projections called **pseudopods** (false feet) or by flagella or cilia. Certain parasitic protozoa also show gliding movements. Others like *Vorticella* are fixed in one place with a stalk. The protozoans feed mostly on solid food particles. The parasitic forms (such as the malarial parasite) live in the bodies of man, other animals and plants, and absorb dissolved food from the host. Respiration and excretion take place directly through the cell membrane. The protozoa reproduce both asexually and sexually, and many of them have complicated life histories. They are found nearly everywhere—in ponds and pools, in and on animal and plant bodies, on decaying leaves, in the soil, and so on, wherever there is a trace of water and some organic matter.

AMOEBA—A REPRESENTATIVE PROTOZOAN

One of the commonest examples of the Protozoa is *Amoeba* (Fig. 29.1) which occurs on decaying leaves and twigs in ponds. It is hardly visible to the naked eye, but if you examine the debris from a pond under a microscope, you might mistake the amoeba in it for a particle of some non-living matter On careful observation you will find that the amoeba is made up of an irregular mass of jelly-like protoplasm surrounded by a thin membrane, moving very slowly. The cytoplasm is differentiated into two fairly distinct regions—an outer thin, clear **ectoplasm** and an inner mass of granular **endoplasm**. Contained within the latter are numerous crystalline particles, a number of food-filled spaces (vacuoles), a large spherical nucleus, and a clear spherical space (contractile vacuole) containing some liquid

The cytoplasm is in a state of constant flow and as it presses against the thin cell membrane, a blunt projection or pseudopod may be formed at any point. Gradually, a large amount of cytoplasm flows into the newly formed pseudopod. Soon another pseudopod is formed at some other point and the cytoplasm now flows in that direction. Thus the animal goes on changing its shape and position. This type of movement is called the **amoeboid movement.**

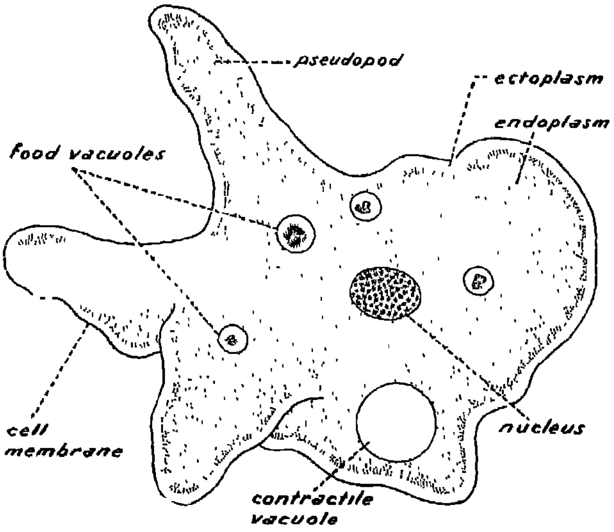


Fig. 29.1. *Amoeba* as seen under the high power of the microscope.

If you watch long enough, you may see an amoeba move up to a tiny bit of food particle. Two pseudopods flow out, one on either side of the particle They meet beyond it and fuse to form a vacuole around it (Fig. 29.2). The **food vacuole** moves through the cytoplasm and as it does so certain enzymes diffuse from the cytoplasm into the vacuole and digest the food. The digested food is finally absorbed into the surrounding cytoplasm whereas the undigested matter passes out through any point in the cell membrane.

The oxygen required for respiration is obtained from the water in which the amoeba lives. The dissolved oxygen diffuses into the cytoplasm through the cell membrane. The carbon dioxide and the other waste matter produced as the result of metabolism pass out in a similar way into the surrounding medium.

The cytoplasm accumulates an excess of water as the result of diffusion and its own metabolic activity. Lest such continuous accumulation result in the bursting of the animal, the surplus water is pumped out by means of a special structure called **contractile vacuole** which appears as a clear spherical space in the cytoplasm. As soon as the vacuole is filled with water (containing traces of soluble waste products), it moves to the surface and bursts. Meanwhile a new vacuole appears and the process is repeated.

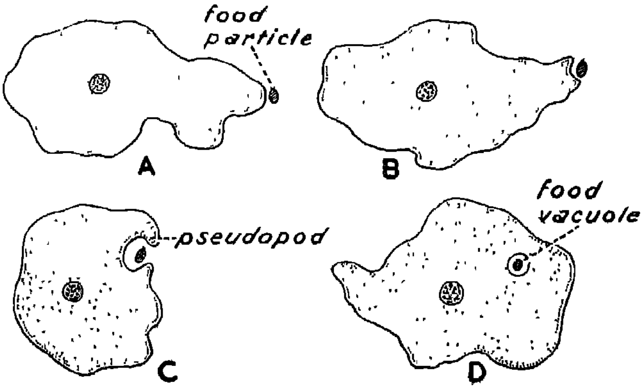


Fig. 29.2. Ingestion of food by *Amoeba* A and B. Formation of pseudopods around the food particle. C. Pseudopods encircling the food particle. D. Food vacuole in cytoplasm.

The amoeba shows responsiveness to various external stimuli. When exposed to strong light it moves about until it finds itself in darkness or dim light. It is attracted to food particles but not to the inorganic matter. If you touch it with a microneedle or place a little acid in the neighbourhood, it moves away. It also responds to changes in temperature. Like all other protoplasm its activity slows down at low temperatures but increases at high temperatures provided they are within the limits of tolerance

As the food is digested, some of it is built up into new protoplasm and the amoeba continues to grow. After it has reached a certain size the animal starts reproducing. The most frequent method is simple cell division or **binary fission** (Fig. 29.3 A to E). In this process the body of a fully grown amoeba becomes slightly elongated, the nucleus divides into two, and eventually the cell cleaves into two parts each containing a nucleus. In this way the original amoeba gives rise to two smaller amoebas which grow and divide in their turn Thus, unless the animal is accidentally killed, it never faces natural death. In other words the amoeba is **potentially immortal !**

Sometimes when the water dries up, the amoeba may round up into a ball and form a protective covering or cyst. In this form it can withstand unfavourable conditions for a long period. The protoplasm inside the cyst may divide into several small amoebas. This process is known as **multiple fission.** With the return of normal conditions, the cyst ruptures and the young amoebas come out into the water (Fig 29 3 F).

Amoebas may be obtained for laboratory work by scraping the decaying vegetation from the bottom of a pond into a wide-mouth container containing pond water and allowing the scraping to settle. A large number of amoebas of different kinds would be found in the sediment. A rich culture of amoebas can also be prepared by soaking

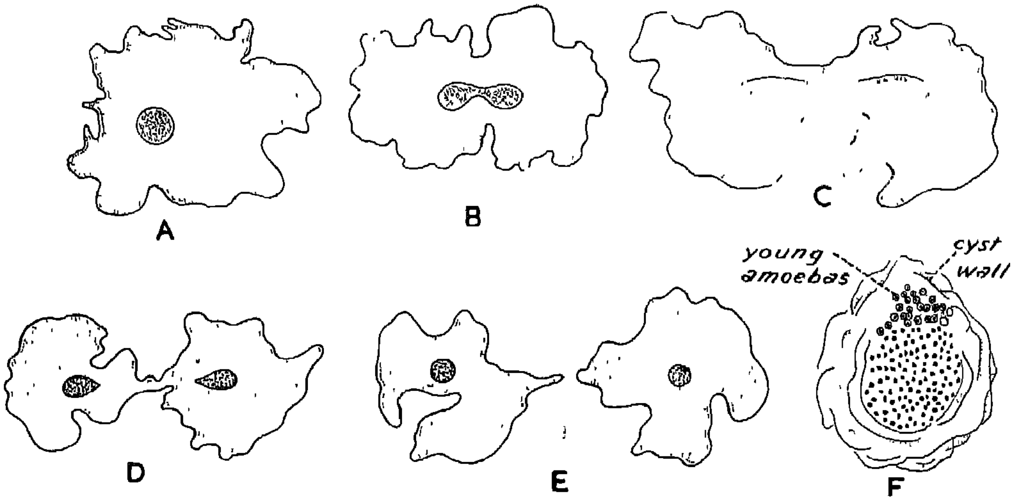


Fig. 29.3. Asexual reproduction in *Amoeba*. A to E. Stages in binary fission. F. Encysted amoeba containing young amoebas.

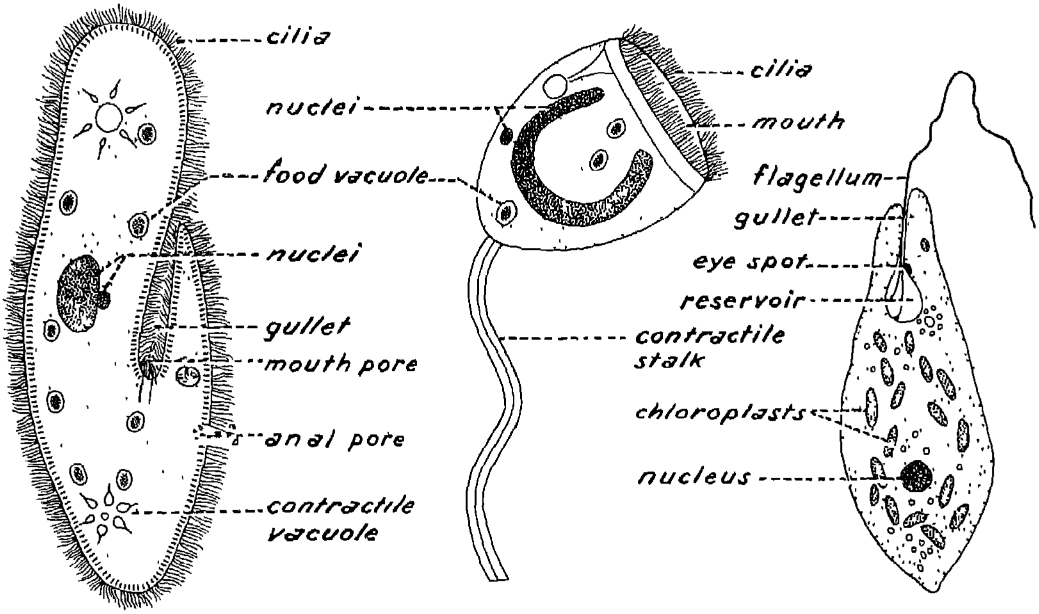
grass roots and semi-dry leaves in pond or rain water (chlorinated tap water is poisonous for protozoans) in jars with loose covers for about a week Amoebas can be sorted out from this culture with the help of a fine pipette.

Some other fascinating forms in protozoa are *Paramecium*, *Vorticella* and *Euglena* (Fig. 29 4).

Protozoan Parasites of Man

The protozoa living as parasites inside the bodies of man and other animals may cause serious diseases Three important disease-producing protozoa in man are *Plasmodium* (malarial parasite), *Entamoeba* and *Trypanosoma.*

Plasmodium (Malarial Parasite). Most of you may have heard of malaria. The disease is characterized by high fever and shivers which recur every 48 or 72 hours. It is caused by a protozoan known as *Plasmodium* The parasite is transmitted by the bite of the female mosquito of the genus *Anopheles*. You can recognize this kind of mosquito by its peculiar standing posture It stands with its body held at an angle to the surface (Fig. 29.5). When a female



PARAMECIUM VORTICELLA EUGLENA

Fig. 29.4. **Some other protozoa.** *Paramecium* **has a permanent shape like that of a slipper. The outer surface is covered with cilia which serve for locomotion. Unlike amoeba, it has definite openings for ingestion and egestion. Note that this animal has two nuclei.** *Vorticella* **is a bell-shaped protozoan attached to aquatic plants by means of a long stalk which contracts and coils at the slightest disturbance in water. The mouth of the bell bears a ring of cilia. Note the horseshoe-shaped large nucleus and the spherical small nucleus.** *Euglena* **has a spindle-shaped body with a flask-like gullet. The animal swims about in pond water by lashing its long flagellum. It contains an eye-spot and many chloroplasts.**

mosquito bites and sucks the blood of a malaria patient, some of the parasites pass into the insect's stomach A number of these behave as the male and female cells, and fuse in pairs to form zygotes. The latter become somewhat elongated and penetrate the stomach wall where they grow and multiply to form spindle-shaped cells called **sporozoites.** Finally the sporozoites migrate through body fluids to the salivary glands of the mosquito When such a mosquito bites a healthy person, these cells are transmitted into his blood. They first invade the liver where they multiply enormously. Later they enter the red blood cells Inside each attacked blood cell, the parasite enlarges and divides into numerous daughter cells called **merozoites.** As the red cells burst the merozoites are set free in the blood. Each of these attacks a fresh red cell and repeats the cycle (Fig. 29.5) With the release of the merozoites

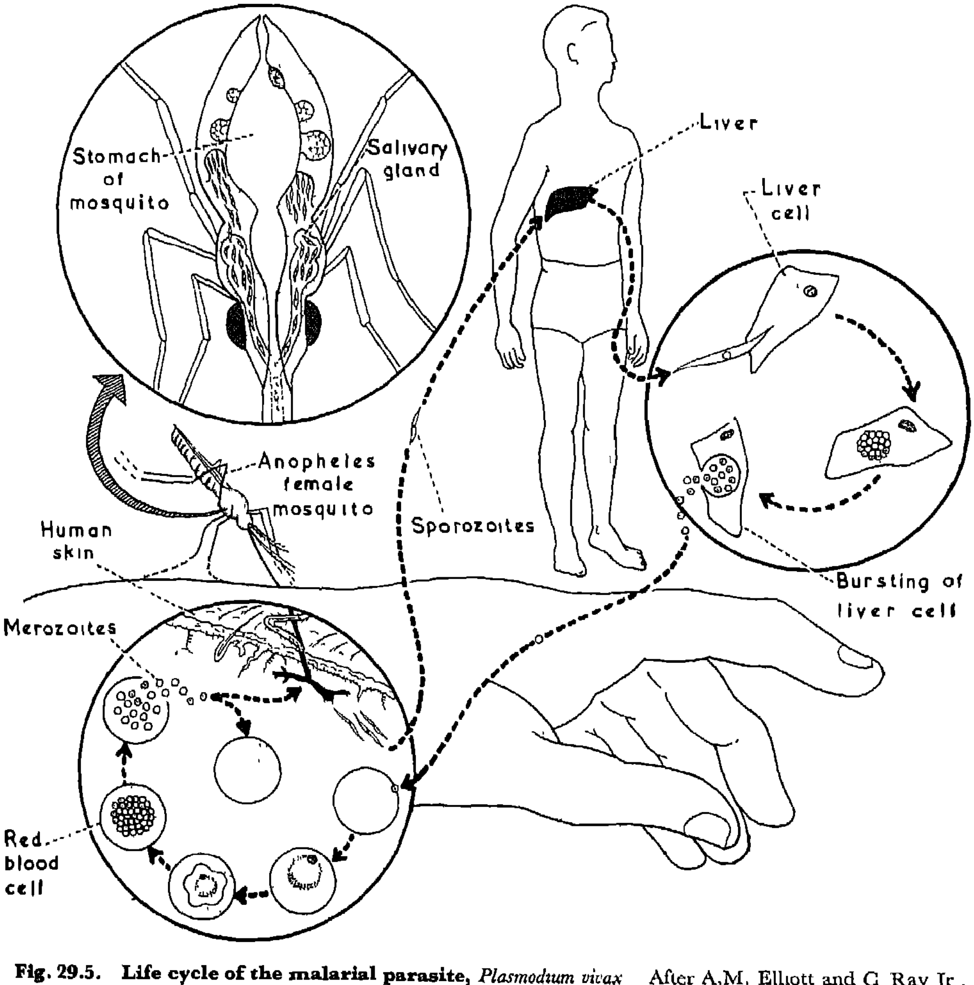


Fig. 29.5. Life cycle of the malarial parasite, *Plasmodium vivax* After A.M. Elliott and C Ray Jr, *Biology*, Appleton-Century-Crofts, Inc, New York, 1960.

in the blood the person experiences a chill and sweating fever. The interval between the bite of a mosquito and the onset of fever is called the **incubation period.**

Four species of malarial parasite are known to infect man *Plasmodium vivax* and *Plasmodium ovale* form merozoites that burst out of the red blood cells in 48-hour intervals (every second day), *Plasmodium malariae* does the same in 72 hours (every third day) and *Plasmodium falciparum* in 36 to 48 hours.

Malaria is wide-spread in most tropical and subtropical countries. A few years ago about a million people used to die annually from this disease in India, but now it has been almost eliminated

Entamoeba. This is another protozoan parasite common in our country. The species *E. histolytica* causes **amoebic dysentery** or **amoebiasis.** This disease is characterized by pain in the abdomen and repeated motions. The stools of the patient contain large amounts of blood and mucus.

In structure *Entamoeba* resembles amoeba but the pseudopods are more transparent, the food vacuoles contain red blood corpuscles, and the contractile vacuole is absent (Fig. 29.6 A). It forms a smooth spherical cyst containing two to four nuclei (Fig. 29 6 B). The entamoebas and their cysts pass out of the body along with faecal matter. Infection occurs when one happens to take water or food contaminated with the cysts. The parasite usually lives in the large intestine, invading and destroying the intestinal lining. It may enter into deeper tissues and damage the blood capillaries. Sometimes it is carried with the blood stream to other organs like liver, spleen, lungs and brain, and may grow there and produce pus-filled swellings or abscesses.

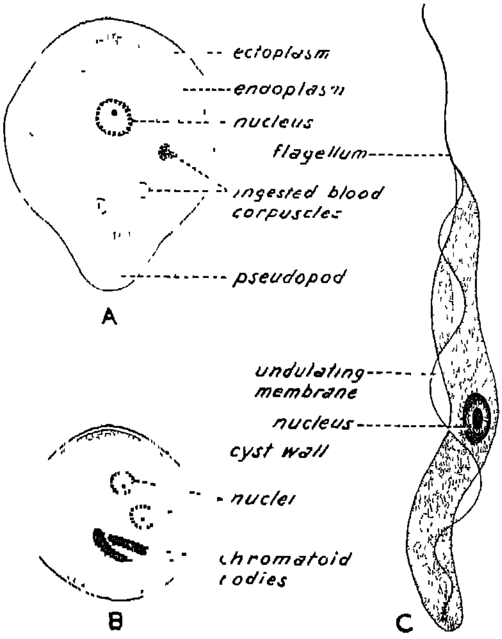


Fig. 29.6. Parasitic protozoa. A and B. *Entamoeba histolytica,* **the organism causing amoebic dysentery in man. A. The organism as seen under the microscope. B. Encysted entamoeba; the cyst can withstand unfavourable conditions. C.** *Trypanosoma gambiense* **It causes sleeping sickness, a dreadful disease prevalent in certain parts of Africa.**

Trypanosoma. This parasite causes a dangerous disease called **sleeping sickness,** prevalent in some parts of Africa. The patients develop high fever and acute weakness, and frequently fall asleep for short or long periods. The organism is a slender, flat cell with an undulating membrane and a flagellum on one side (Fig. 29 6 C) Trypanosomes live in the blood of wild animals which do not seem to suffer. However, when the parasites are transferred from wild animals to man by blood sucking

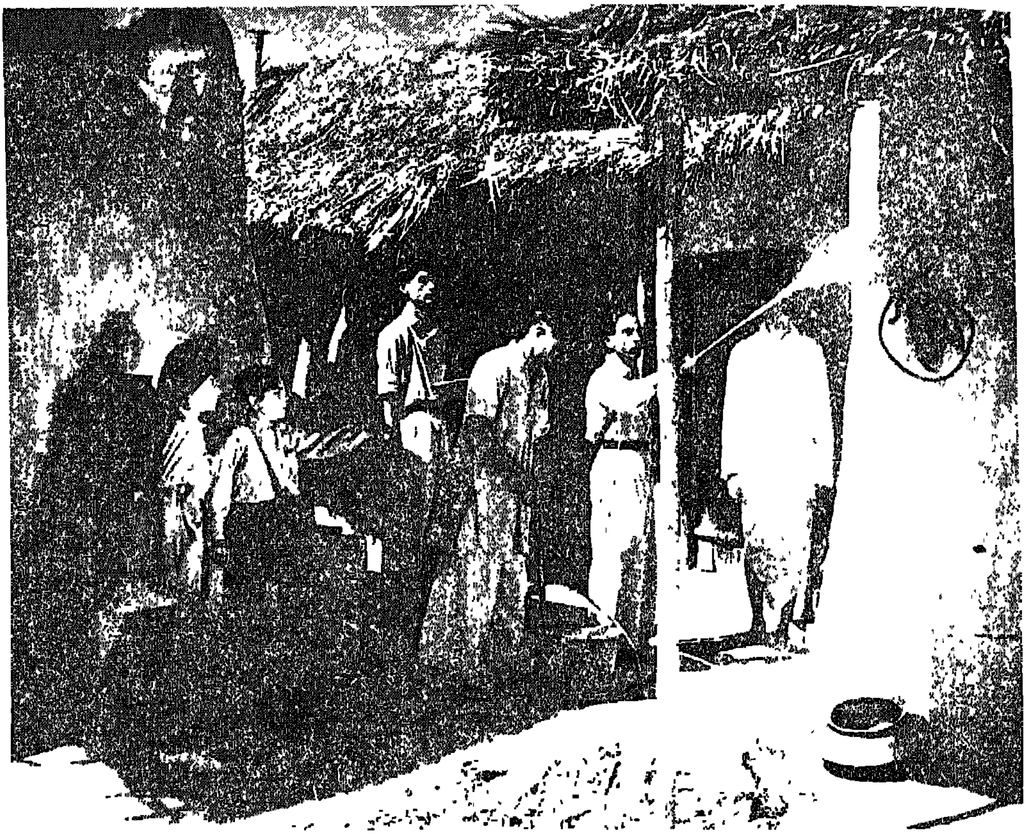


Fig. 29.7. A house being sprayed with insecticide for protection against mosquitoes. Courtesy of the United Nations.

insects like the tsetse fly, symptoms of the disease soon make their appearance.

Control Measures

The most important and effective step in controlling the protozoan parasites is to adopt hygienic habits Unfiltered drinking water or water which may have been contaminated should be boiled or treated chemically before use. Food should be properly cooked, and vegetables and fruits well washed before eating. In areas infested with mosquitoes, nets should be used to save oneself from their bites

For checking the spread of infection, measures may be adopted to kill the various carriers both in their adult and larval stages. The mosquitoes, for instance, breed in marshy places like ponds, pools and ditches. These should be drained or covered with a thin film of oil which prevents the respiration of the larvae, thereby causing their death. The breeding of mosquitoes is further effectively checked by stocking the lakes with fish which eat mosquito larvae.

The adult carriers can be killed by spraying insecticides like DDT in the corners and crevices of houses which form the hiding places for the insects (Fig. 29.7)

SUMMARY

The protozoa are unicellular animals found in all places where water and organic matter are available Some forms live as parasites in man and other animals. All the activities of life take place within the single cell constituting the animal

Amoeba is a common freshwater protozoan. It is just an irregular mass of protoplasm changing its shape as it moves on by extending pseudopods. In addition to the nucleus, an amoeba contains one or more food vacuoles and a contractile vacuole. It reproduces by binary fission and is therefore potentially immortal. Under unfavourable conditions it forms a cyst within which a large number of amoebas are formed. When favourable conditions return, the young amoebas are set free.

Three important parasitic forms are *Plasmodium*, *Trypanosoma* and *Entamoeba* *Plasmodium* or the malarial parasite lives part of its life in *Anopheles* mosquito and part in the human body. *Trypanosoma* causes sleeping sickness and is spread by the tsetse fly. *Entamoeba,* which resembles amoeba in most respects, infects the large intestine and causes amoebic dysentery. The usual control measures include killing of the carriers and adopting hygienic habits.

QUESTIONS

1. If your teacher asked you to bring a protozoan to the class, where would you look for it?
2. Describe the sexual and asexual methods of reproduction of the protozoans studied by you.
3. Malaria literally means ‘disease of bad air’. Do you think one could escape malaria by avoiding bad air alone?
4. What do you understand by ‘sleeping sickness’? In which parts of the world is this disease more prevalent?
5. What steps are being taken by the municipal authorities of your town to kill mosquitoes?
6. What stages of the life history of malarial parasite are passed in the mosquito?
7. How does a knowledge of the life history of a disease-causing protozoan help in controlling the disease?
8. Why does a dysentery patient pass out mucus and blood with his stools?
9. Some people think that the statement, "*Amoeba* is potentially immortal", is not quite correct. What do you think about this remark?

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CHAPTER 30

Porifera—The Pore-Bearing Animals (Sponges)

SPONGES are the lowest and the simplest o multicellular animals. The natural bath sponge sold in the market is really the skeleton of a sponge animal. Most sponges live in the sea though some are also found in lakes and ponds. They are attached to rocks, weeds and other submerged objects, and grow by branching in a plant-like manner. Sponges exhibit a variety of colours. They are green, pink, red, yellow and sometimes white or even colourless. Because of their varied colouration, branching form and sedentary mode of life, the sponges can be easily mistaken for plants.

Structure of a Simple Sponge

A simple sponge is a tuft of numerous cylindrical upright tubes united at their bases by horizontal tubes forming a colony (Fig 30.1). Each tube is a thin-walled sac bearing a large number of minute pores (**ostia**) all over its surface and a large opening (**osculum**) at the top. The wall is made up of an outer layer of flat epithelial cells and an inner lining of flagellated collar cells. In between the two layers is a gelatinous substance containing numerous wandering amoeboid cells (Fig. 30.2 B). The flagella of the collar cells beat to and fro and cause a constant inflow of water. Water enters through the minute pores into the large central cavity and passes out

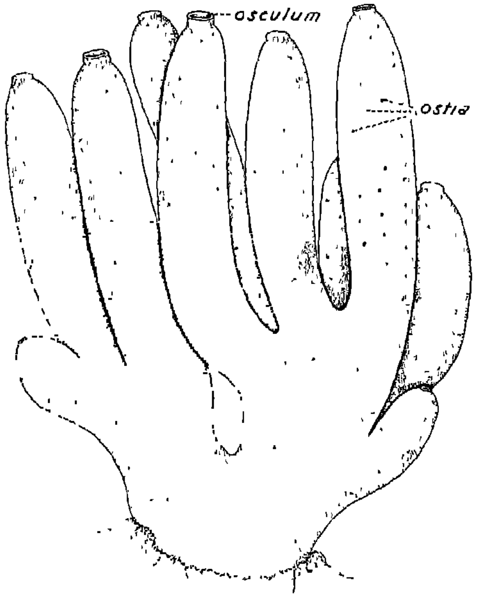


Fig. 30.1. Part of a colony of a simple sponge.

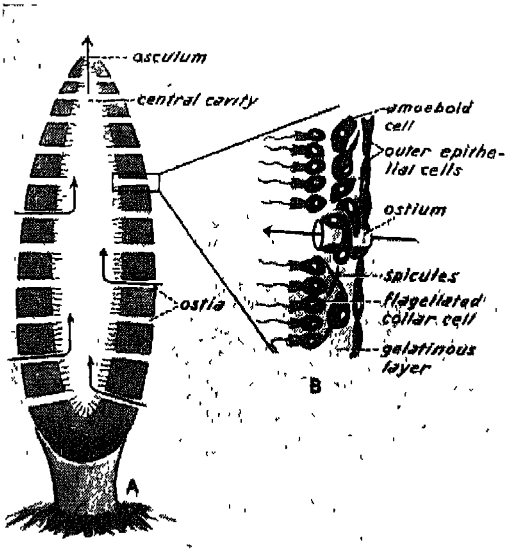


Fig. 30.2. **The internal structure of a simple sponge. A. Diagrammatic representation of longitudinal section of the entire animal. B. Part of the body wall (marked in A) magnified.** Adapted from P.B Weisz, *An Introduction to Biology*, McGraw-Hill Book Company, Inc, New York, 1963

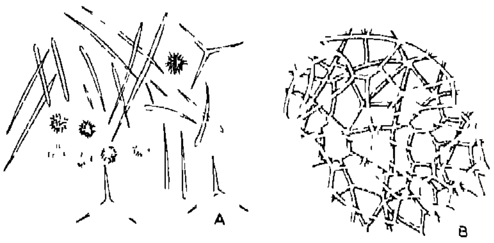


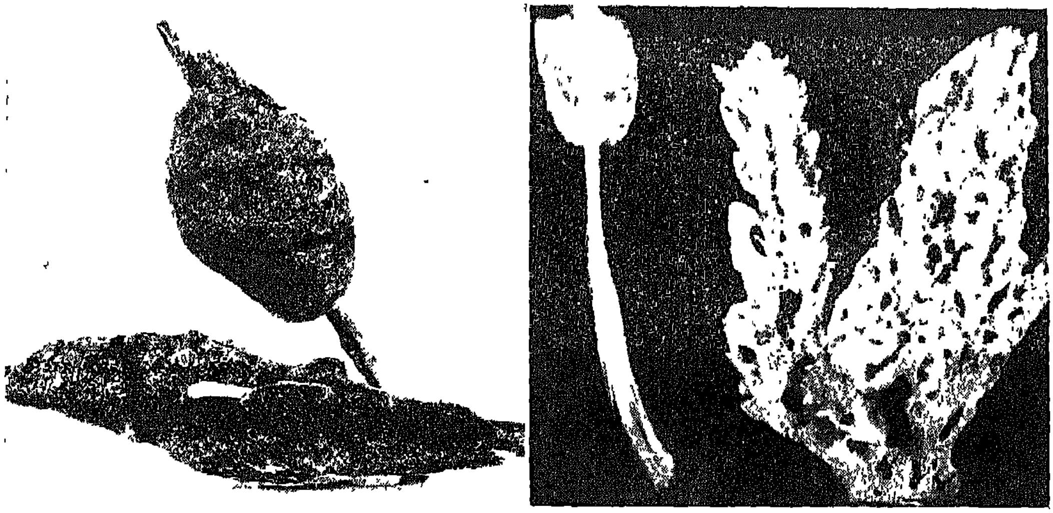
Fig. 30.3. **Skeleton of sponges. A. Spicules of various shapes. B. Spongin fibres.**

through the top opening (Fig 30 2 A) This water current brings in food and oxygen and removes the waste products. The food particles (minute organisms) are caught by the collar cells and are either digested by these cells directly or are passed on to the amoeboid cells contained in the underlying gelatinous substance.

The gelatinous layer also contains a skeleton of calcareous or siliceous material in the form of **spicules.** The simplest of these are needle-like while others have three or more rays (Fig 30.3A). The spicules are numerous and overlap one another forming a network in the body wall. In the bath sponge the skeleton forms a network of flexible **spongin fibres** (Fig 30 3 B).

Sponges reproduce either asexually by forming buds or sexually by means of eggs and sperms. Most sponges are **hermaphroditic,** producing both eggs and sperms on the same individual The mature gametes are liberated into the water.

Sponges have a remarkable power of regeneration. Even a small fragment is capable of growing into a complete animal Not only that, a sponge crushed into a pulp and strained through a fine silk cloth, shows individual cells in the filtrate, and these cells can again aggregate into masses and grow into new animals In areas where sponges are grown commercially, a big sponge is cut into small pieces which are lowered into the sea in small cages. The pieces begin to grow into huge sponges in a few years. Some of the common types of sponges are shown in figure 30.4. The fibrous skeleton of sponges is used for bathing and washing, as absorbents in surgical operations, and as packing or padding materials.



FRESHWATER SPONGE

GLASS ROPE SPONGE

BATH SPONGE

Fig. 30.4. Three kinds of sponges. The freshwater sponge grows attached to aquatic plants. Courtesy of the American Museum of Natural History, New York **The glass rope sponge is cup-like and composed of siliceous, six-rayed spicules interwoven into a beautiful network attached to the rocks by long glassy fibres. This sponge is found in the deeper regions of the Pacific Ocean. The bath sponge occurs in big masses attached to rocks in the sea. The commercial sponge is actually the dried skeleton of this animal. Famous bath sponges come from Turkey. They are collected by divers or by means of hooks attached to long poles. When fresh, they are slimy and jelly-like.**

SUMMARY

Sponges are the simplest of multicellular animals. Due to their sedentary habit and colourful appearance they are often mistaken for plants All sponges have numerous tiny holes in their bodies They are found mostly in the sea but a few also occur in freshwater

Sponges have a framework of delicate spicules or spongin fibres or both. They reproduce sexually by means of eggs and sperms, and asexually by producing buds. They also have a pronounced capacity for regeneration.

A simple sponge is a bag-like, cylindrical structure with numerous pores all over its surface. Water enters into the body through these pores and comes out through a large opening situated at the top The inflow of water is caused by a regulated beating of flagella borne on collar cells The skeleton of sponges is used for bathing, washing, packing, etc.

QUESTIONS

1. Describe the organization of a simple sponge. How does it obtain food and oxygen ?
2. What is the significance of the pronounced regenerative capacity of sponges ?
3. In what respects do sponges resemble plants? What is your argument for regarding them animals?
4. Why are sponges considered to be more advanced than protozoa?

FURTHER READING

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CHAPTER 31

Coelenterata— The Hollow-Sac Animals

THE coelenterates are multicellular animals that are more highly organised than sponges. They are found mostly in the sea but a few occur in freshwater. If you collect a water plant, *Hydrilla*, with a little pond water in a glass jar and leave it undisturbed for some time, you may be able to see some tiny whitish thread-like bodies attached by their basal ends to the plant (Fig. 31.1). At the free end of each thread there are present 5 to 6 tentacles. This animal is known as *Hydra*. Other coelenterates—jellyfishes, sea anemones (sea flowers) (Figs. 31.2 and 31.3) and corals are found in the sea. All these forms have a radial symmetry. They are diploblastic; their body wall is formed of two layers—the **epidermis** and the **gastrodermis** or endodermis. Between these two layers is a non-cellular material (**mesogloea**). In certain regions the epidermis bears **stinging**

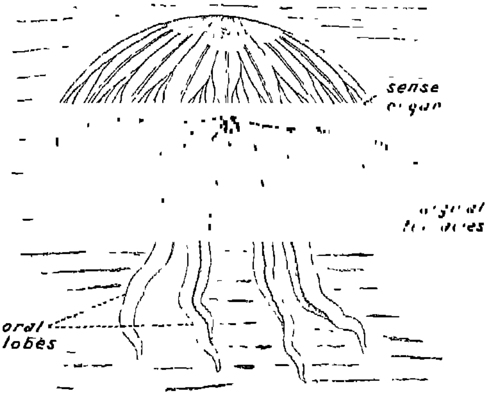

Fig. 31.2. The jellyfish, a marine free-swimming coelenterate. The body is like an inverted saucer bearing a large number of marginal tentacles and eight sense organs. The mouth is situated in the centre of the lower surface between the four oral lobes. The food reaches the mouth through the grooves in the lobes.

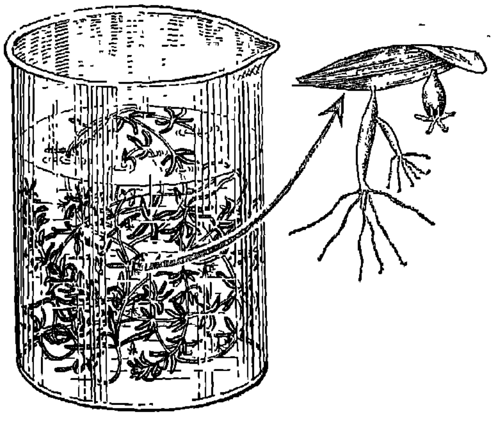

Fig. 31.1. A pond weed, *Hydrilla*, collected in a glass jar to show hydras growing on its leaves.

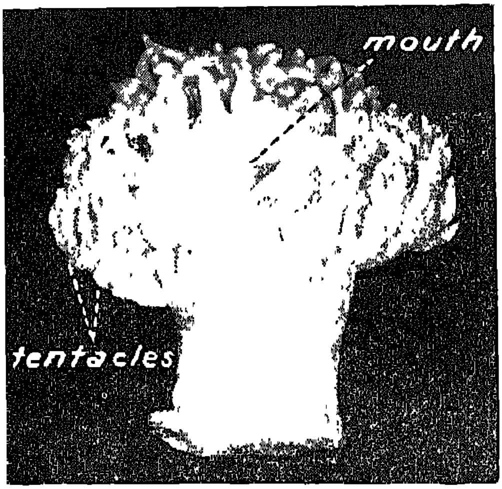

Fig. 31.3. **The sea anemone or 'flower of the sea'. Its cylindrical body is attached to the rocks at one end, and bears a large number of tentacles around the mouth at the other end. When the tentacles are fully extended, the animal looks like a big flower.**

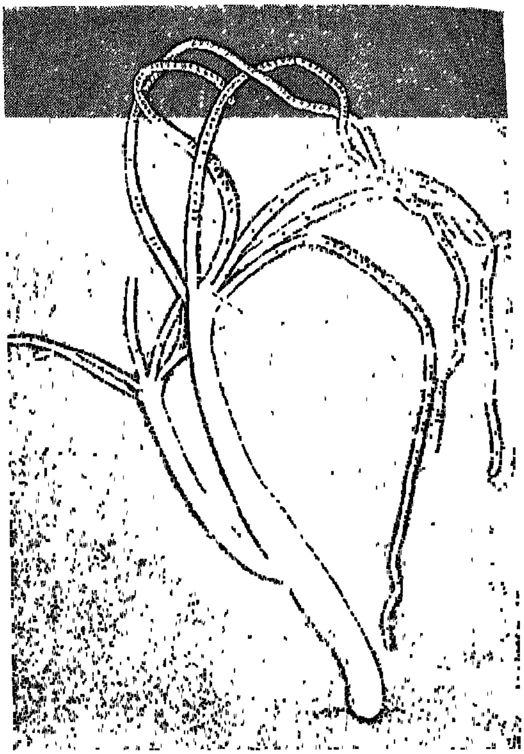

Fig. 31.4. ***Hydra*****, a freshwater coelenterate. Note the parent and a daughter hydra.** After R. Buchsbaum, *Animals Without Backbones*, University of Chicago Press, Chicago, 1948.

cells. The gastrodermis encloses a cavity, the **enteron**, which serves both for the digestion and the circulation of the nutrient material.

HYDRA

Hydra occurs on submerged stones and plants in freshwater. Its cylindrical body may be 2 to 12 mm in length. The free end bears a circlet of 5 or 6 slender tentacles (Fig. 31.4) surrounding a central cone-like area which bears an opening, the 'mouth', at the apex. The body is highly extensible, sometimes elongating to more than twice its normal size. At the slightest disturbance in the water, the animal contracts to form a tiny lump.

The examination of a longitudinal section of the body of a hydra shows the epidermis and gastrodermis with the mesogloea separating the two (Fig. 31.5). Most of the cells in both the layers bear contractile processes along the mesogloea. Due to the activity of these processes, the hydra is able to stretch or contract its body. The tentacles are hollow and contain the same two layers of cells. Certain cells in the epidermis are specialized to form stinging cells. These are specially abundant on the tentacles which are mainly used for catching small organisms for food. The stinging cells are little sacs containing a poisonous fluid. One end of the sac is produced into a long, hollow thread

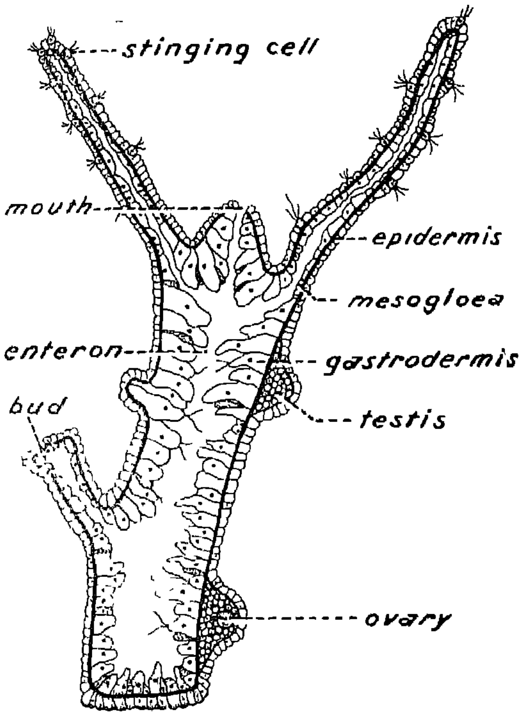

Fig. 31.5. The internal structure of *Hydra* as seen in a longitudinal section. The body is made of just two germinal layers.

which remains coiled inside the cell. Projecting from the sac is a sensitive hair. When an organism touches the sensitive hair, the coiled thread is violently shot out. Some threads entangle the prey while others inject poison into it. The prey, thus paralysed by the poison, is carried by the tentacles into the 'mouth'.

The gastrodermis is made of large cells. The free ends of certain cells are either produced into pseudopods or bear one or two flagella. The food caught by the tentacles is pushed through the 'mouth' into the enteron where it is mixed with the digestive juices secreted by the glandular cells of the gastrodermis. The cells with pseudopods may also engulf small fragments of food from the enteron and digestion may take place within the cells The indigestible matter is forced out of the enteron through the 'mouth' which now performs the function of an anus.

At the base of epidermal cells, close to mesogloea, there are numerous nerve cells linked together to form a fine network throughout the body and the tentacles. This nervous network is connected with a number of sensory cells scattered throughout the epidermis and gastrodermis

Most of the time the hydra remains fixed at one spot, but sometimes it does move about to more favourable places This movement is performed either by a looping action or by somersaulting (Fig 31 6).

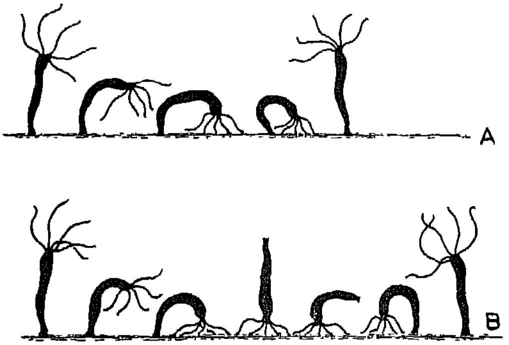

Fig. 31.6. Locomotion in *Hydra* A. Looping movement. B. Somersaulting.

In the first, the body is bent over till the tentacles touch the surface to which it is attached. In this position the animal assumes the shape of a loop. Next, the basal part relaxes its hold and moves up to the tentacles where it takes a fresh grip, thus covering a little distance The tentacles are then released and the animal becomes upright, In somersaulting, the fixed end of the body turns over (somersaults) to gain a new hold on the other side of the tentacles. Occasionally, the hydra is detached from its original position and is drifted to a new place by a strong current of water.

There are no definite organs for respiration and excretion. All the cells of the epidermis and gastrodermis use the oxygen dissolved in water and give out carbon dioxide and other waste materials by the process of diffusion.

Hydra reproduces both asexually and sexually. In asexual reproduction, a small bud is produced as a hollow outgrowth from the body wall (Figs. 31.4 and 31.7A). Within a few days it elongates and develops the tentacles and a 'mouth' at its free end. This young hydra later becomes detached from the parent and settles as an independent individual (Fig. 31.7 B).

In sexual reproduction, each animal develops both male and female sex organs (testes and ovaries respectively) and is, therefore, a hermaphrodite. The testes appear as conical outgrowths, usually situated in the upper half of the body. When fully developed, they rupture and release the sperms in water. The ovaries are rounded structures located near the lower end of the body. Each ovary contains a single large egg surrounded by nurse cells. The outer covering of a mature ovary ruptures and the sperms swim into it. The ripe egg is fertilized by one of the sperms. The fertilized egg develops into a double-layered embryo which becomes detached from the parent. Later the embryo attaches itself to some substratum by one end and develops mouth and tentacles at its free end. Normally the testes and ovaries in an individual do not mature at the same time; thus self-fertilization is avoided.

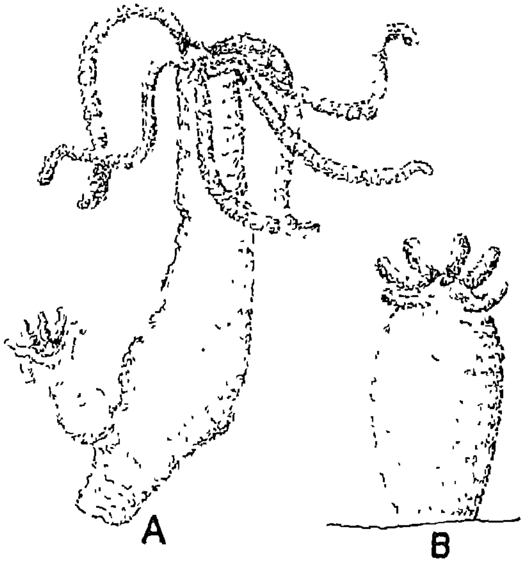

Fig. 31.7. Asexual reproduction in *Hydra*. A. Parent hydra with a small bud. B. Young hydra established from a bud.

Hydra has a remarkable power of regeneration. If it is cut into two parts (upper and lower), each part will grow the missing region—the upper will produce the base and the lower will form the mouth and the tentacles.

CORALS

Special mention may be made of certain anemone-like coelenterates called **corals** (Fig 31.8). They usually form large colonies and secrete calcareous or horny skeletons around themselves. As these colonies expand, huge deposits of lime form ridges or reefs. The Great Barrier Reef off the north eastern coast of Australia is about 1,800 km long and 80 km wide. Coral deposits are used for making jewellery and other pieces of art found in fancy stores all over the world.

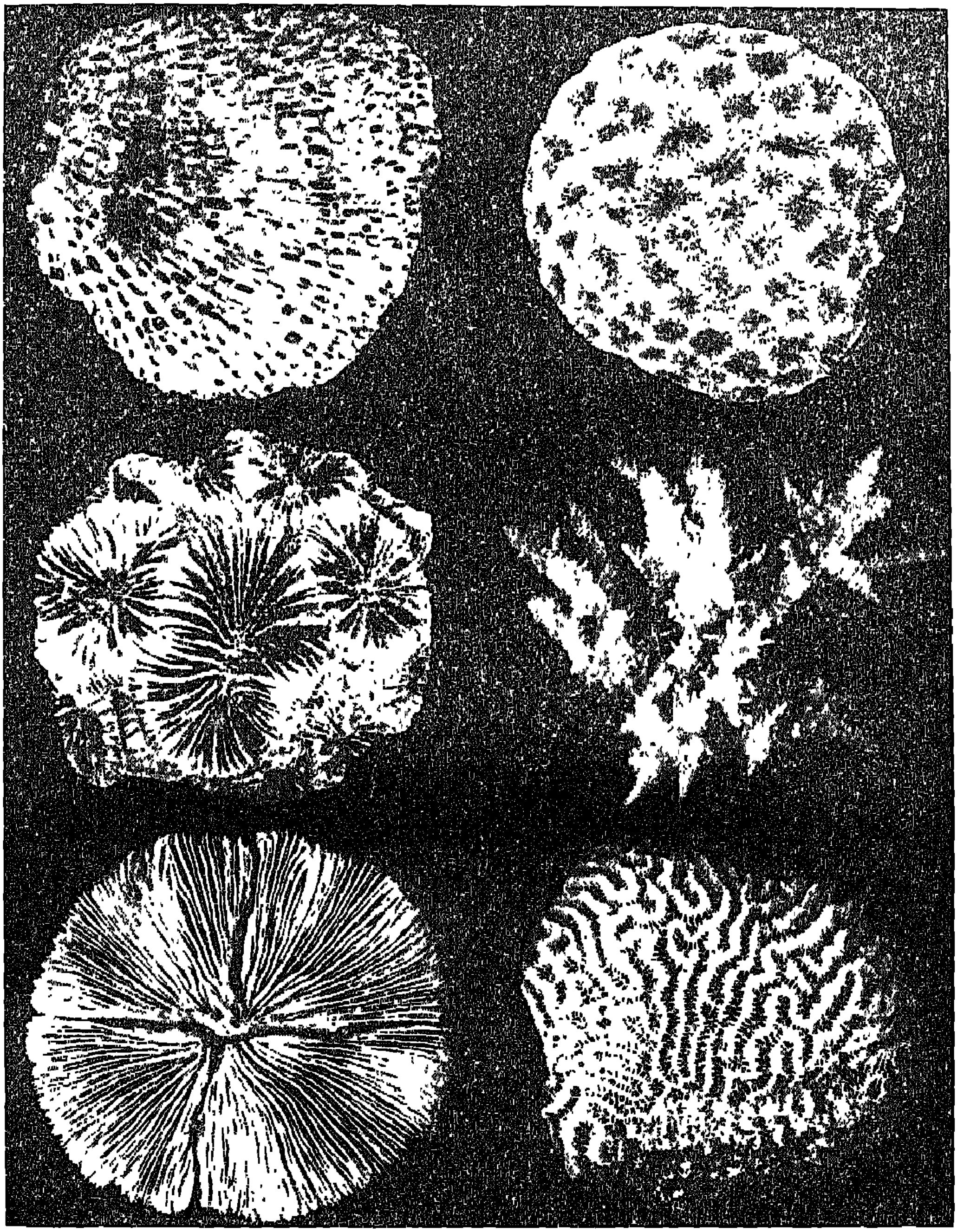

Fig. 31.8. A selection of corals. These are hard calcareous skeletons secreted by certain coelenterates. From the minute pores in this framework the hydra-like branches of the animals peep into water.

SUMMARY

The coelenterates are simple animals Their body is like a hollow sac bearing a number of tentacles near the 'mouth' The wall of the sac is made up of two cell layers, the epidermis and the endodermis. There is also a non-cellular cementing layer or mesogloea in between the two. All over their surface, the coelenterates bear stinging cells which are specially abundant on the tentacles

Hydra, a freshwater coelenterate, grows on submerged plants and stones It looks like a white thread with a number of tentacles at the free end. In contrast to the structure of a sponge, the cells composing a hydra show a greater differetniation Thus, there are contractile cells, stinging cells, glandular cells and nerve cells Although primarily a fixed form, hydra can move from one place to another either by looping or by somersaulting Asexual reproduction in hydra occurs by means of buds which arise as hollow outgrowths of the body wall. In sexual reproduction, the sperms released from the testes fertilize the eggs contained in the ovaries. The fertilized egg in each ovary grows into an embryo which becomes detached from the parent and then establishes itself as an independent animal.

Other common examples of coelenterates are jellyfishes, sea anemones and corals The corals secrete calcareous skeletons around themselves. These deposits often become very massive.

QUESTIONS

1. What characters will you look for in an animal in order to place it among the coelenterates?
2. Where will you look for hydras?
3. What makes the body of a hydra so extensible?
4. Describe the food catching mechanism of a hydra.
5. How does the 'mouth' of a hydra differ from that of a higher animal?

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CHAPTER 32

Platyhelminthes— The Flatworms

THE platyhelminths or flatworms often remain unnoticed on account of their parasitic mode of life, although some are also free-living. To a student of biology these animals are of great interest: first because they cause several ailments in man and other animals, and secondly because they show the beginning of a complex organization which becomes still more pronounced in the higher animals. Their tissues are derived from three embryonic layers, instead of two as in coelenterates. The third layer is the mesoderm which gives rise to the body muscles, reproductive organs and a spongy parenchymatous tissue. There is, however, no coelome or body cavity in these worms. The flatworms are compressed in the dorso-ventral plane, and have therefore a bilateral symmetry. The alimentary canal, when present, has no anus. The excretory system consists of numerous branching tubes ending in special structures called flame cells. These worms are usually hermaphroditic.

FASCIOLA (LIVER FLUKE)

In most countries the liver fluke is a common parasite in the liver of sheep and other cattle. It badly damages the liver and causes **'liver rot'**. The liver fluke has a flat leaf-like body (Fig 32.1). There are two adhesive structures, known as **suckers**; an oral sucker at the front end and a ventral sucker a little behind it The mouth, situated in the oral sucker, leads into a highly branched alimentary canal occupying the whole body (Fig. 32.1). The anus is absent The excretory and reproductive systems are also highly branched and complex.

When the liver fluke lays its eggs they travel from the liver of the sheep to its intestine through the bile duct and finally come out with faeces (Fig. 32 2). Eggs deposited near water hatch into tiny free-moving larvae which enter the body of a snail. The subsequent development inside the snail consists of a series of larval stages and at each stage there is an increase in the number of individuals The final type of larva has two suckers and a narrow tail. With the help of its tail, it wriggles out of the snail and moves freely in water till it reaches some small plant near the edge of the pond. At this stage the tail is lost, the larva settles on a blade of grass and forms a cyst around itself. These cysts are swallowed by the main host (sheep) when it feeds upon the contaminated grass On

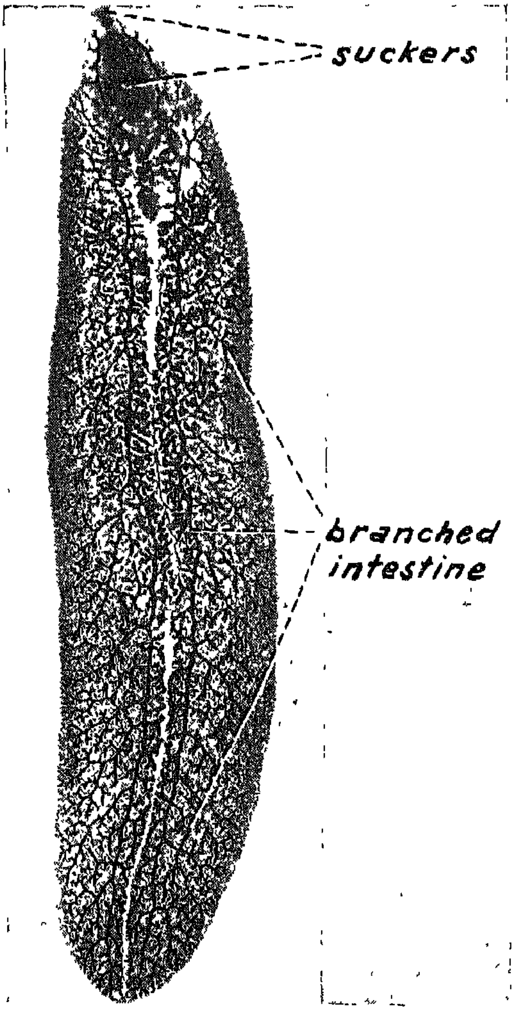


Fig. 32.1. The liver fluke of sheep (*Fasciola*) The specimen has been stained to make the internal organs visible. The network spread in the entire body is the alimentary canal and branched gonads.

reaching the sheep's stomach the cyst dissolves and the young worm is liberated. The latter bores through the wall of the stomach and finds its way into a blood vessel, finally reaching the liver. A young fluke attains maturity in three to four months and can safely live for several years, feeding on the contents of the liver of its host

TAENIA SOLIUM (TAPEWORM)

The tapeworm is a parasite in the intestine of man. It has neither mouth nor alimentary canal. Its white or light yellow ribbon-like body may be as much as three to six metres long. At the front end there is a tiny head behind which the body is divided into a large number of segments (Fig. 32.3) These are of three kinds. (1) small immature segments, just behind the head, in which the organs have not yet differentiated, (2) mature segments, containing the male and female reproductive organs; and (3) gravid segments which form the hind part of the body and are full of fertilized eggs. The head is the organ of attachment. It bears 28 hooks and four cup-shaped suckers. The rest of the body of the animal hangs freely in the intestine from the head.

The end segments containing ripe eggs pass out with the faeces of man. Further development is possible only if the eggs are swallowed by a pig (Fig. 32.3) Inside the pig's stomach each egg hatches and sets free an embryo with six hooklets. With their help the embryo bores through the stomach wall and enters some blood vessels, finally reaching the muscles of the pig. Here it grows into a globular structure called the **bladder worm** which is enclosed in a thin covering and bears a small head with hooks and suckers. When pork infected with bladder worms is eaten by man, the worms may attach themselves to the intestinal wall and start budding segments and developing into adults.

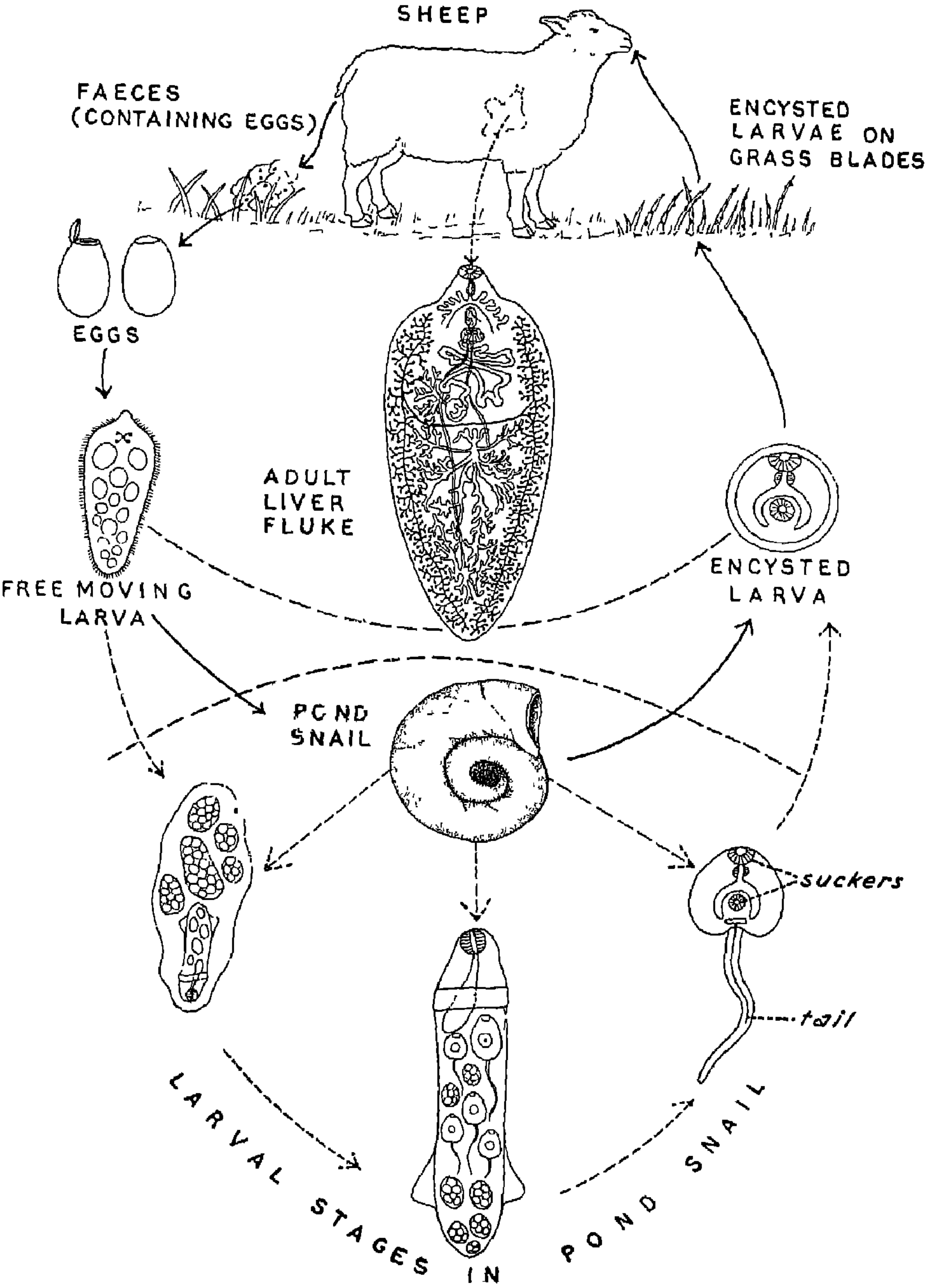


Fig. 32.2. Life cycle of the liver fluke.

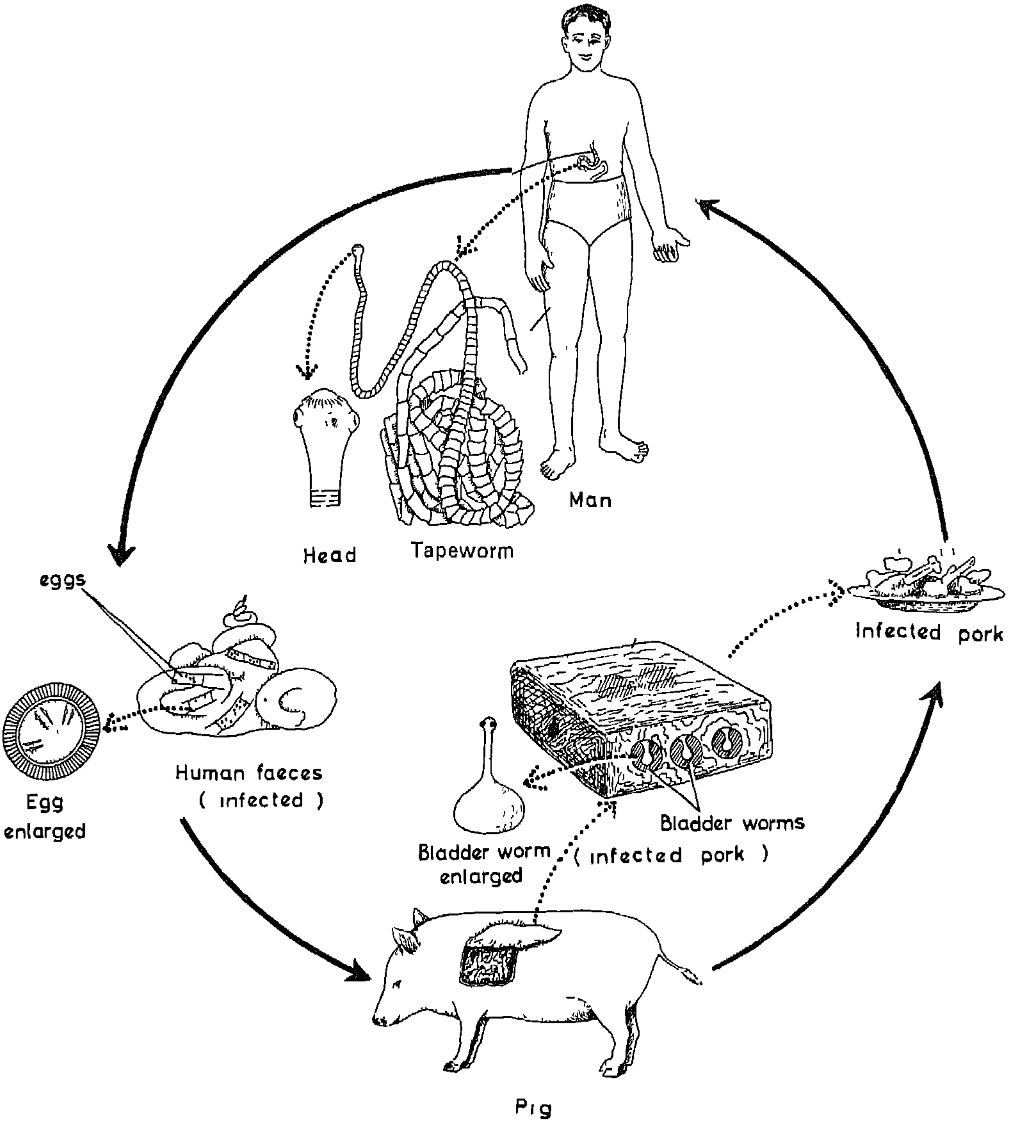
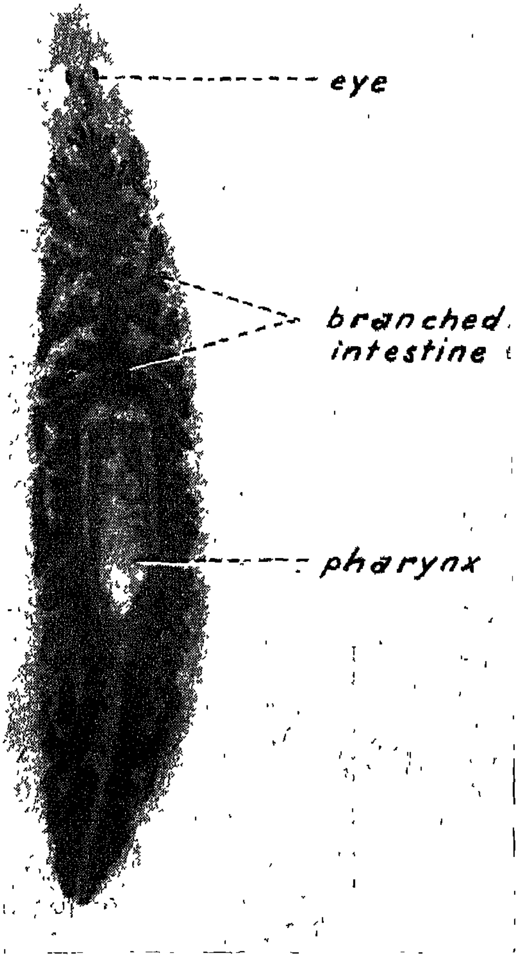


Fig. 32.3. Life cycle of the tapeworm (*Taenia solium*) of man.

You have seen that the liver fluke as well as the tapeworm complete their life cycle in two different hosts. The host, which harbours the adult stage (bearing a fully developed reproductive system), is known as the principal or final host (sheep for liver fluke, man for tapeworm). The other hosts (snail for liver fluke and pig for tapeworm) having the larval stages are known as intermediate hosts. For a completion of the life cycle, it is essential that both the hosts are available.

THE PLANARIANS (FREE-LIVING FLATWORMS)

The planarians are free-living flatworms found in sea, in freshwater and on land all over the world Some are brilliantly coloured The freshwater forms, found at the bottom of ponds, are small, flattened worms, a few millimetres in length The anterior end is broad whereas the other is more or less pointed (Fig. 32 4) On the dorsal surface, close to the anterior extremity, there are two rounded black spots, the eyes. The eyes are merely light-sensitive structures and have no lenses, retinal structure, etc Hence unlike man and other animals, they are incapable of camera vision. The mouth is present on the ventral side and through this the pharynx can be everted out. The ciliated epidermis helps the body in gliding along the substratum. The alimentary canal is well-developed, much branched and without an anus *Planaria* has a remarkable capacity for regeneration It has become famous because of the numerous experiments done on it.



ig. 32.4. *Planaria*, **a freshwater flatworm. The specimen has been stained to show the internal structure. The food is taken in through the pharynx situated at the centre of the body.**

SUMMARY

The platyhelminths or flatworms are mostly parasitic although a few forms are free-living They are triploblastic, i.e. they have three embryonic layers. However, there is no well-defined body cavity. *Planaria* is a small freshwater flatworm and is a favourite material for experiments on regeneration for which it possesses great capacity.

The liver fluke, a parasite in sheep (primary host), passes a part of its life history in the body of the pond snail (intermediate host) The fluke lays a large number of eggs which travel from the sheep's liver to its intestine from where they are discharged with faeces. The eggs hatch into free-living larvae which get into the body of a snail. The subsequent larval stages not only serve to bring the parasite nearer to its adult form but also multiply its number. The tailed larvae wriggle out of the snail's body and become encysted. When a sheep happens to swallow the cysts sticking to the grass, young worms are set free into its stomach from the cysts. Boring through the stomach wall, the worms enter the blood vessels and reach the liver. Here they grow into adult flukes within a few months and feed upon the cells of the liver.

The tapeworm is an intestinal parasite of man. It attaches itself to the intestine by means of hooks and suckers borne on its tiny head. The rest of the body, consisting of a large number of segments, hangs in the intestine. Gravid segments containing a large number of fertilized eggs continue to be detached from the free end of the animal and pass out with human faeces If the eggs happen to be swallowed by a pig, they liberate embryos which travel to the pig's muscles and develop into bladder worms. If improperly cooked pork containing these worms is taken by man he becomes infested with them

QUESTIONS

1 Of what advantage is it to a tapeworm to produce a large number of eggs?

2. Where does the liver fluke lay its eggs?

3 How are the platyhelminths more advanced than the coelenterates as regards their (*i*) digestion, (*ii*) excretion and (*iii*) body organization?

4. How do we get tapeworms in the body? Ask your teacher about the measures adopted to get rid of them

5. Who are more likely to get tapeworms: vegetarians or non-vegetarians?

FURTHER READING

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CHAPTER 33

Nemathelminthes—The Roundworms

LIKE the flatworms, many of the roundworms or nemathelminths are also parasites in man and other animals Some forms inhabit freshwater and damp soil Still others are found in close association with the roots or stems of plants Those present in the roots of crop plants like tomato and tobacco cause heavy losses either by lowering their productivity or by killing them.

Roundworms have elongated, cylindrical, unsegmented body with a thick covering (cuticle). There are three basic or embryonic layers in the body but unlike the flatworms, a well-developed body cavity is also present The alimentary canal has a posterior anal opening The sexes are separate and the male worms are usually smaller than the female

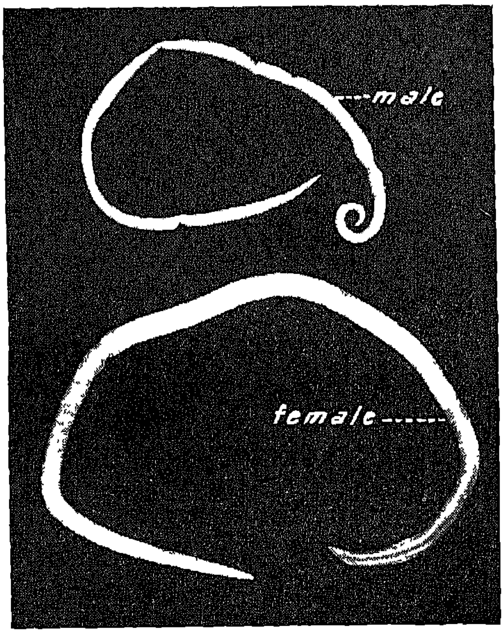

Fig. 33.1. The common roundworm (*Ascaris lumbricoides*). Note that the male has a curved tail-end.

ASCARIS LUMBRICOIDES

Ascaris lumbricoides is the common roundworm found in the intestine of man in all parts of the world It has been known from very early times. The adult female is 25–30 cm in length and has a straight tail-end The adult male is smaller, with its tail-end sharply curved like a hook (Fig. 33.1) The digestive tract has a distinct mouth and an anus. This worm does not require an intermediate host to complete its life cycle. A single female may produce as many as 200,000 eggs per day. They are passed out in large numbers along with the faeces. In two to three weeks, small embryos develop inside the eggs Such eggs are capable of producing infection if swallowed by man. They reach the human stomach with contaminated food and drinks. The eggs hatch out in the duodenum and the young ones penetrate the blood vessels, finally reaching the lungs. The young worms soon move from lungs to the pharynx from where they once again enter the alimentary canal In the intestine they get plenty of food and grow into the adult worms

HELMINTHS AND DISEASE

Parasites belonging to both Platyhelminthes and Nemathelminthes are often spoken of as helminths. They are responsible for a number of diseases in man and other animals. A few of these are mentioned below.

You have already read about the 'liver rot' caused by *Fasciola* in sheep and cattle (Fig. 33.2). In severe cases of infection a large portion of the liver may disintegrate thus affecting its normal working and even bringing death to the host. An allied type of fluke (*Fasciolopsis buski*) attacks the liver of man. The encysted larvae are found attached to the skin of horn-nut or 'singhara'. The parasite enters the human system when the skin of this fruit is peeled by biting with teeth. *Taenia solium*, the common tapeworm, robs the patient of a large proportion of his food. The head of the worm injures the intestinal wall, and ulcers may be formed due to subsequent bacterial attack. The hydatid tapeworm (*Echinococcus granulosus*) is another flatworm (Fig. 33.3) which parasitizes the intestine of dog. Since man has a great association with dogs, the eggs of the parasites may also reach his intestine (especially in children) from where they are carried to the liver and lungs. In these organs they form round masses called **hydatid cysts** which may sometimes attain the size of an orange They prevent the proper functioning of the infected organ and often prove fatal to the patient. **Schistosomiasis** is another dangerous disease caused by little blood flukes called schistosomes (Fig. 33.3). They live in the blood of man and other animals and are responsible for damage to blood vessels resulting in the loss of blood. *Enterobius* or **pinworm** (Fig. 33.3) is a very minute roundworm inhabiting the human rectum. The females travel down to the anal region to deposit the eggs and cause an itching sensation by their wriggling movements. *Ancylostoma*, the **hookworm** (Fig. 33.3) lives in the intestine of man. It ruptures the blood capillaries of the intestinal wall and causes loss of blood. *Ascaris*, the common large roundworm of man, causes indigestion, discomfort and pain in the abdomen, diarrhoea and inflammation of the intestine. If the worms become numerous (Fig. 33.4) these ailments are intensified. Filaria worms (Fig. 33.5 A) cause a disease known as **elephantiasis** in which the affected parts of the body (usually legs) become greatly swollen (Fig. 33.5 B). The worms are transmitted through certain kinds of mosquitoes.

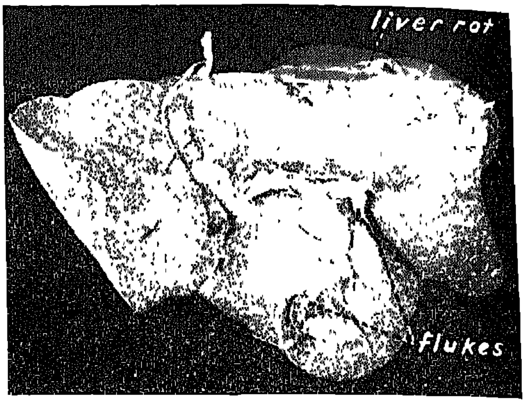

Fig. 33.2. Sheep's liver infected with liver flukes. Courtesy of L.N. Johri, Department of Zoology, University of Delhi.

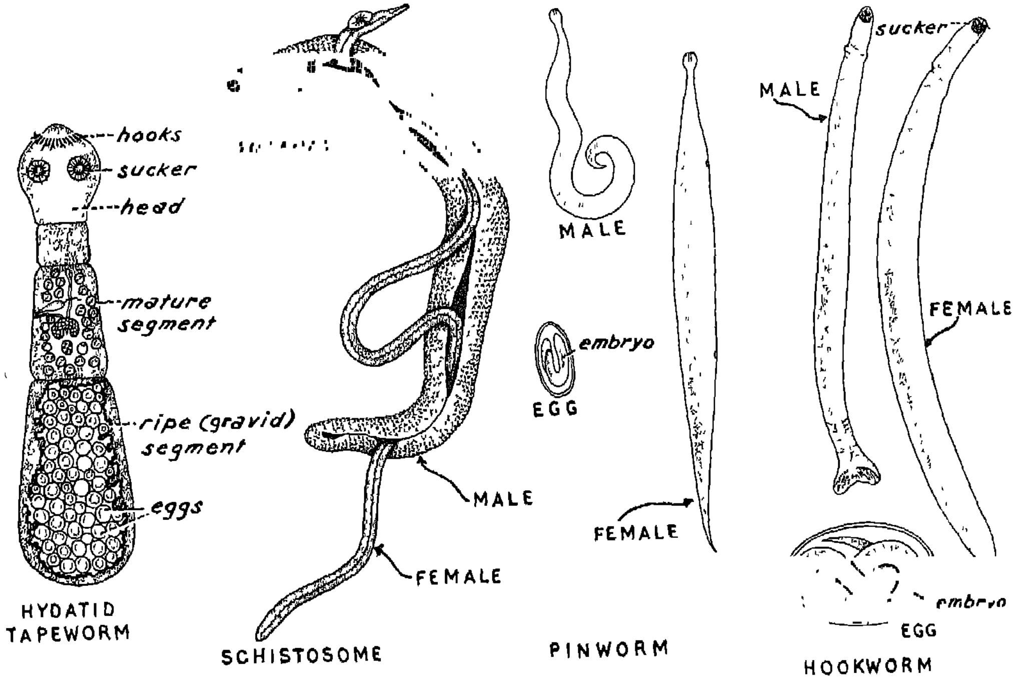

Fig. 33.3. **Some parasitic helminths. The hydatid tapeworm (*Echinococcus granulosus*) is parasitic in the intestine of dog. Its adult body is rather short, consisting of just three segments following the head. Sheep (and sometimes man) become infected by swallowing its eggs. The eggs hatch into larvae called hydatid cysts. *Schistosoma* is a flatworm causing schistosomiasis. The female worm is slender and lives in a groove on the ventral side of the male. The pinworm (*Enterobius*) is a small, cylindrical worm found in the human rectum. The hookworm (*Ancylostoma*) is a common parasitic nematode of human intestine. Note the hooks by means of which it ruptures the blood capillaries in the intestinal wall.**

You have seen that most of the helminth parasites gain entry into the human body with contaminated food. It is essential, therefore, that the food is well-cooked before eating. Foodstuffs that are eaten raw should be well washed or otherwise protected from getting contaminated The most important thing is to have a high standard of cleanliness—both personal and of the surroundings.

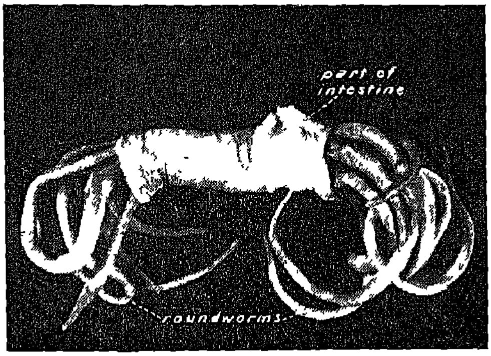

Fig. 33.4. A part of the human intestine infested with roundworms.

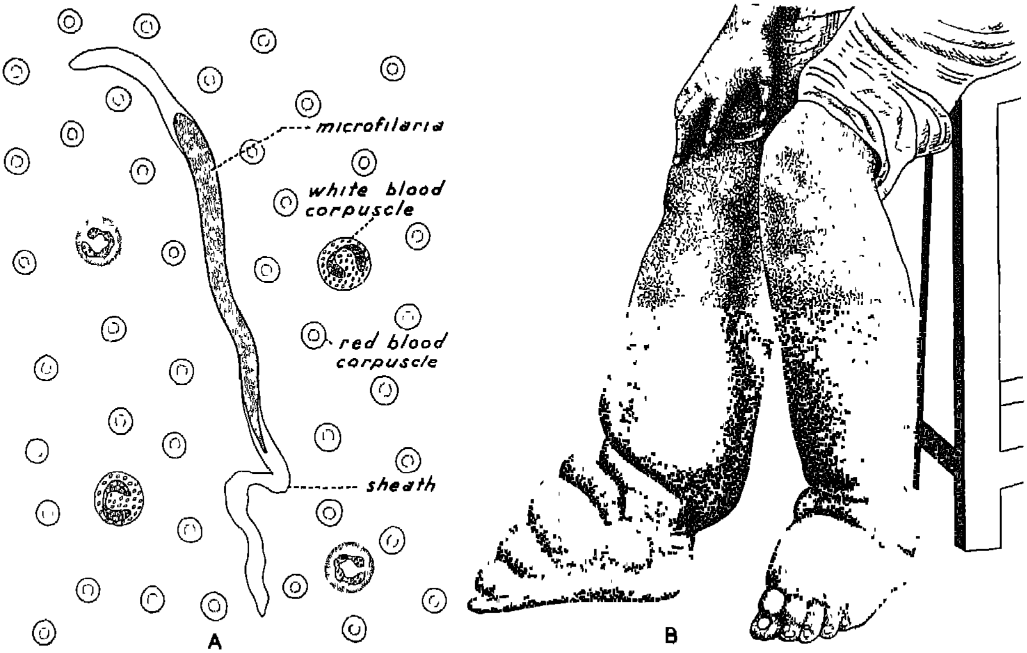

Fig. 33.5. **A.** ***Microfilaria* in the blood of man. This is the larva of the organism that causes elephantiasis. The larvae travel to the blood vessels just under the skin of the victim, especially at night, and are transmitted by certain types of mosquitoes. B. A victim of elephantiasis in the legs.**

Parasitic Adaptations of Helminths

The parasitic worms live on or inside other animals and have become variously specialized to lead this type of life. The body is covered with a cuticle which provides protection against the digestive juices of the host. For holding themselves firmly in the body of the host they have well-developed organs of attachment, such as suckers (liver fluke) or both hooks and suckers (tapeworm). There is a complete absence of the organs of locomotion, of offence and defence, and of special senses. The digestive system is very simple (absent in tapeworm), branched and without an anus in the liver fluke. They can respire in the absence of oxygen. In those worms which require two hosts for the completion of their life cycle, the larval stages are exposed to various accidents during their transmission from one host to the other. This risk is covered by producing an enormous number of eggs.

SUMMARY

The roundworms may be parasitic or free living Some of them are associated with the underground parts of plants. The cylindrical body of a roundworm is covered with a thick cuticle. The sexes are separate, the male being smaller

The commonest member of this group is *Ascaris lumbricoides* occurring in the human intestine. The female lays an enormous number of eggs which are passed out along with the human faeces. Small worms develop in the eggs within three weeks People living under insanitary conditions become infected by swallowing the food and water contaminated with ascaris eggs

The bodies of the worms show a number of adaptations for a parasitic mode of life These include a thick cuticle over the body, suckers and hooks for attachment, absence of locomotary and sense organs, a simple digestive system, and production of innumerable eggs

Helminths are the cause of several diseases in man and domestic animals, mostly damaging their liver or blood vessels. *Ascaris* causes indigestion, and inflammation of the intestine, while *Filaria* worms cause elephantiasis.

QUESTIONS

1 How do we get the following parasites in our bodies—Filaria, tapeworm, roundworm, hookworm and liver fluke?

2 Could snakes and worms be placed in the same phylum? Explain

3 Name the organs of human body through which an ascaris larva passes

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CHAPTER 34

Mollusca—The Shell-Bearing Animals

THE molluscs are soft-bodied, unsegmented animals often covered with a hard shell. Beneath the shell is a soft skin, the **mantle**. The body is distinguishable into a head, a visceral mass and a ventral foot Molluscs have a well-developed digestive system, a three-chambered heart, and a highly organized nervous system. They live in the sea, in freshwater and on land. Only the phylum Arthropoda has more species than Mollusca. The aquatic molluscs respire by means of gills while the land forms respire through lung-like pouches in the mantle. The Indian Ocean abounds in exquisite forms of this group. We shall now acquaint you with a few interesting types.

Bivalve Molluscs

Some molluscs such as clams, mussels, oysters, and scallops (Fig. 34 1) have a laterally compressed body consisting of a visceral mass and a plough-like foot, enclosed in a shell with two halves or valves hinged along the dorsal margin. The valves are opened and closed by one or two powerful muscles. These animals have an efficient water filtering system. Water enters through a tube (inhalant siphon) and is propelled towards the mouth where the food particles contained in the water are taken up. Simultaneously, the water passes on to the gills which absorb the dissolved oxygen for respiration. Eventually the water is expelled through another tube (exhalant siphon). The openings of both the siphons lie near each other on the posterior side (Fig. 34.2). These animals creep on the muddy bottom by means of a foot. The freshwater mussel (*Lamellidens*) is the commonest bivalve mollusc found in our lakes and rivers.

The Indian pearl oyster (*Pinctada vulgaris*) is another interesting bivalve. It is found on our coast in the Gulf of Manaar and in the Palk Bay. Oysters are important since they produce pearls which are of great value An oyster shell has a smooth and silvery inner layer called the mother-of-pearl which is formed by the epithelial cells of the mantle. If a small organism, usually some parasite, gets in between the shell and the mantle, the epithelial cells of the mantle secrete concentric layers of pearly substance around the organism. Gradually this secretion becomes bead-like and is then known as pearl (Fig 34.3). Pearl formation can also be brought about artificially In Japan, fine particles of clam shell are artificially introduced into the oysters which are then kept in wire-cages in

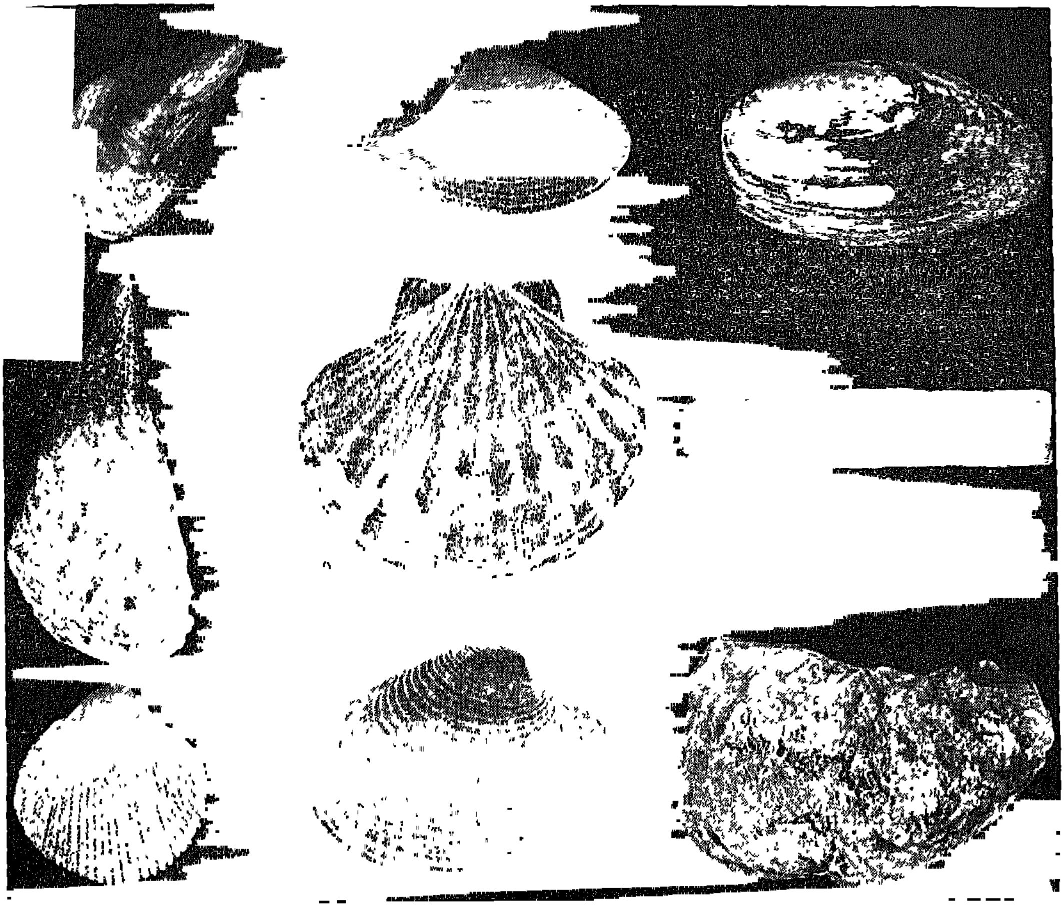

Fig. 34.1. Shells of some common Indian bivalve molluscs.

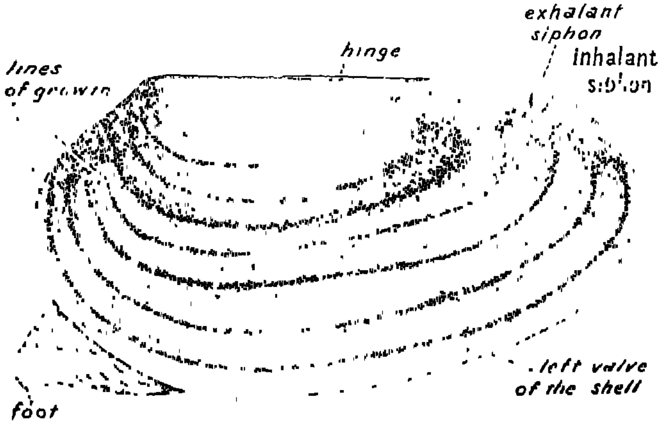

Fig. 34.2. The freshwater mussel (*Lamellidens*) as seen from the left side.

the sea for several years. The pearls thus produced are called 'culture pearls'.

Shipworm (*Teredo*) is a destructive bivalve mollusc which bores into the wooden hulls of ships and causes considerable damage.

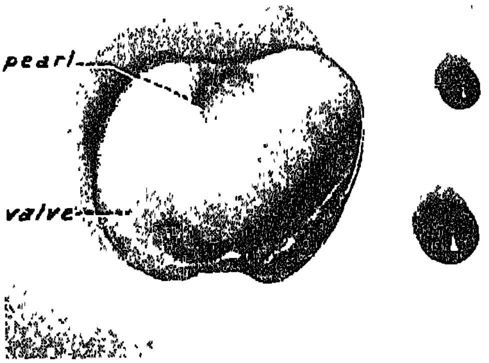

Fig. 34.3. The pearl oyster and the pearls. Courtesy of the American Museum of Natural History, New York

Univalve Molluscs

Most of these organisms have a single cap-like shell which is generally coiled (Fig. 34.4). Common examples are snails, slugs and cowries. These animals crawl on their flat muscular foot and feed mostly on plants. The apple snail, *Pila* (Fig 34.5) is quite common in ponds, lakes and fields. The

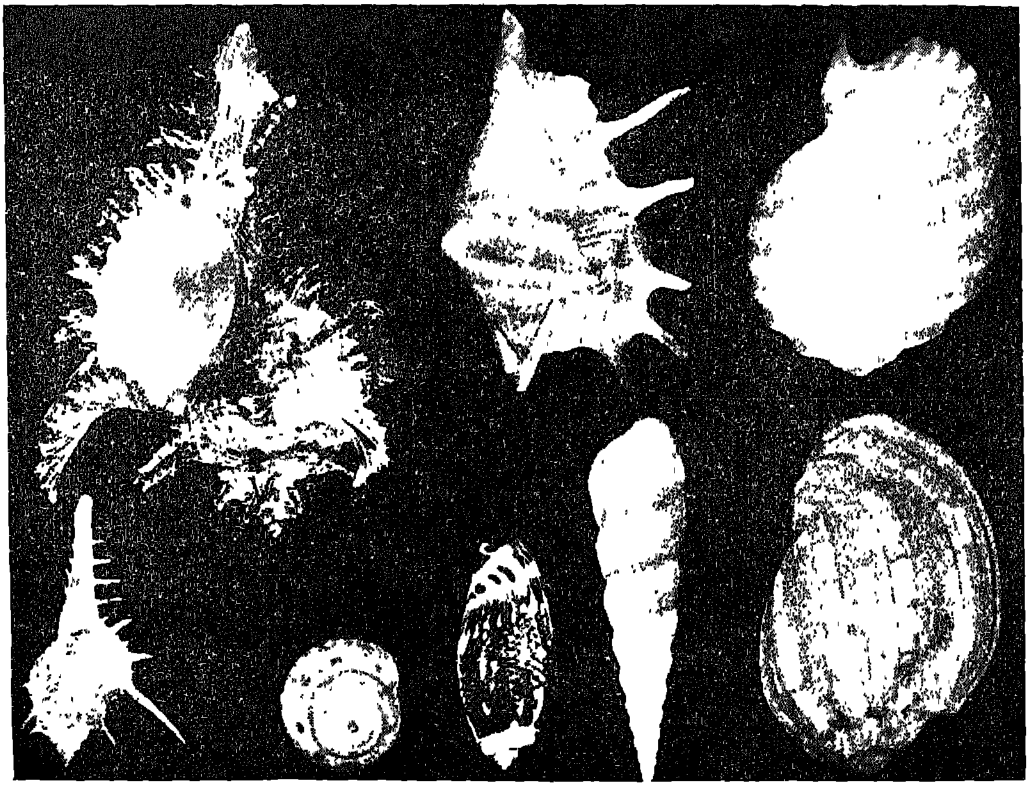

Fig. 34.4. Shells of some common Indian univalve molluscs.

head bears a mouth, two pairs of tentacles and a pair of eyes. The animal moves about by means of a flat foot and respires both by the gill (in water) and the lung-like pouch (on land).

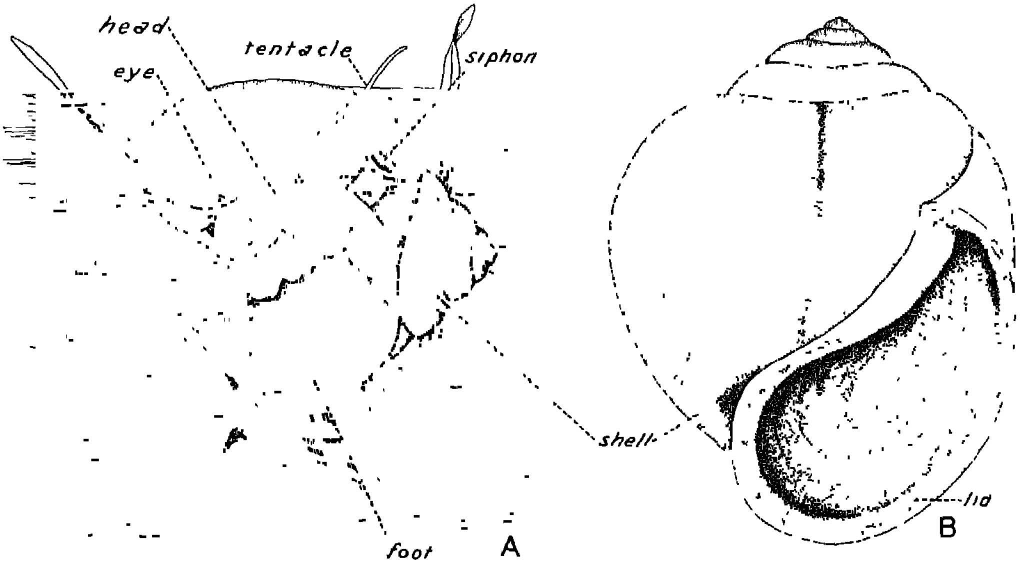

Fig. 34.5. The apple snail (*Pila globosa*). A. The animal in its natural surroundings. Note the foot and the head with extended tentacles. B. Ventral view of the animal with the body retracted into the shell. The opening of the shell is covered by the lid.

Slugs (Fig. 34.6) are snail-like molluscs, quite common in gardens where they feed on the soft parts of plants The shell is absent in the adult slugs

Most of you are perhaps familiar with the large conch shell used in temples. The shell ('shankh') comes from a mollusc known as *Turbinella*. The conch shells are regarded sacred by the Hindus since Lord Vishnu is shown holding it in His hand These animals are gregarious, and are common in shallow waters around our coast They are collected by divers in Tirunelveli, Ramnad, South Arcot and Tanjore districts of Madras State on the east coast, and in Kerala and Kathiawar on the west coast

Cowries are other familiar molluscs which are found hiding under rocks and stones They have beautiful shiny shells. The little yellow cowry (Fig. 34 7) was formerly used as money

Head-Foot Molluscs

These are active animals different in outward appearance from other molluscs They have a conspicuous head with well-developed brain and eyes. A number of sucker-bearing 'arms' surround the mouth at the anterior end of the head. The arms are derived from a structure comparable to the foot of other molluscs.

The cuttlefish (*Sepia*) has ten 'arms'. Eight of these are short and bear suckers

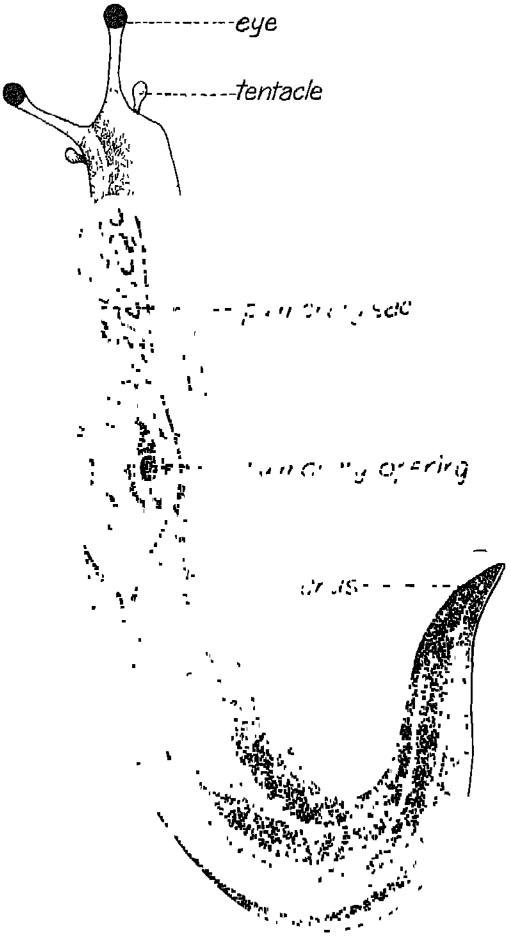

Fig. 34.6. **The land slug; the worm-like body of the adult lacks a shell.**

along their entire length. The remaining two are long with suckers at their terminal ends only (Fig. 34.8) The shell is internal and is popularly called the cuttle bone

The devilfish (*Octopus*) is a highly intelligent relative of the cuttlefish and is devoid of a shell. It has eight equal arms and a

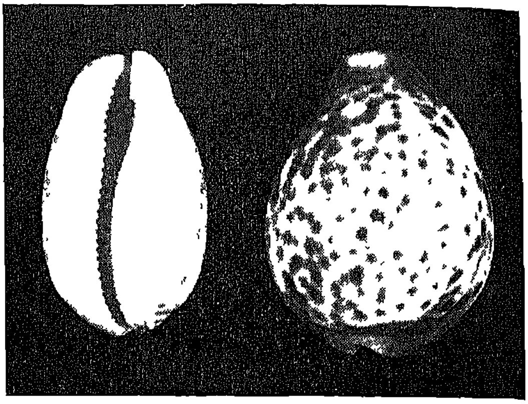

Fig. 34.7. **The money cowry (*Cypraea*). This shell was used as small money in olden days.**

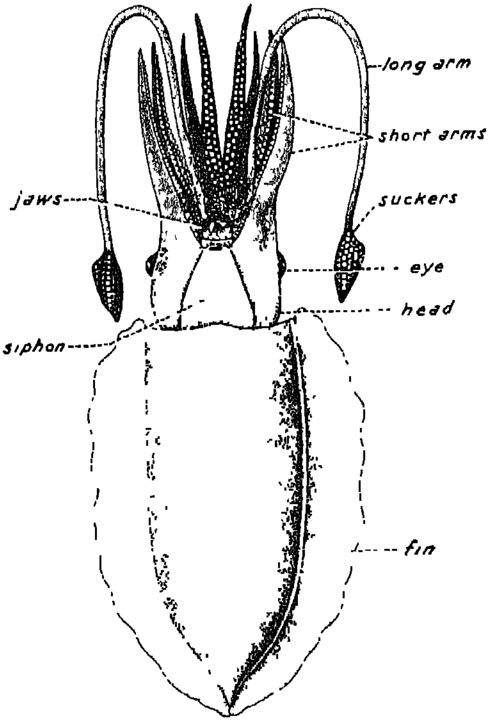

Fig. 34.8. **The cuttlefish (*Sepia*) Its shell is a horny plate imbedded in the mantle. The latter is thick and muscular and has taken over the protective function.**

pair of large eyes (Fig. 34.9). It can crawl as well as swim, but spends most of its time lying on the bottom of the sea, ever ready to catch a prey.

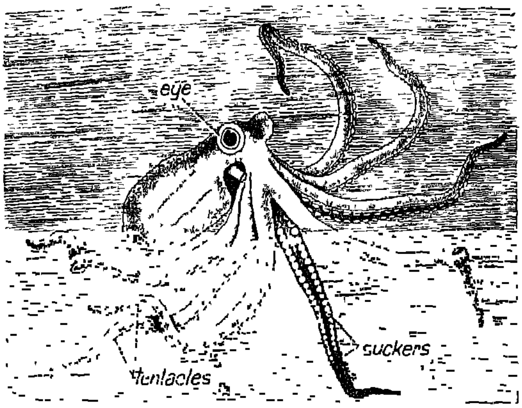

Fig. 34.9. **The devilfish (*Octopus*) The adult animal lacks shell. It can take a firm hold of things with the help of suckers on its eight waving tentacles.**

Economic Importance

Most molluscs are useful animals though some forms like shipworms are harmful. Certain bivalves are eaten all the world over. There are large mollusc cultivation industries in Japan, Europe and America. The cuttlefish and the devilfish are used as food in Ramnad district of Madras State where they occur in abundance in the Palk Bay. Many beautiful shells fetch high prices as decorative pieces Mollusc shells are used for making necklaces, bracelets, eartops and bangles The pearly layer is used for the manufacture of buttons, knife-handles, brooches, toys and many kinds of inlaid work. Shell-lime is fed to poultry to improve egg production The most important industry based on molluscs is the production of pearls.

SUMMARY

Molluscs are fascinating animals, a wide variety of which inhabit both sea and fresh-water. A few forms are found on land They have soft bodies which are usually protected by a calcareous shell. The shell may be a single piece (univalves) or it may consist of two pieces (bivalves). Some forms like the octopus and slug may even lack shells Shells of certain molluscs like clams, oysters, and cowries are valued as articles of decoration and jewellery. A few forms such as the shipworms and slugs are destructive.

QUESTIONS

1. How is a pearl formed? What are natural and cultured pearls?
2. Give two examples of each of the following types of molluscs: bivalves, univalves, head-foot molluscs, molluscs without a visible shell.

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CHAPTER 35

Annelida— The Segmented Worms

THE annelids have a long, bilaterally symmetrical body which is divided into a number of rings or segments. A well-developed body cavity or coelome is present in most of these animals The alimentary canal is a straight tube with mouth and anus at the opposite ends Excretion is carried out by special coiled tubular organs called **nephridia.** The blood vessels and the nerves are well-developed. The body wall itself serves for the exchange of gases The animals are hermaphroditic. The most familiar of them are the earthworms and leeches. Besides these there are many other forms which live in the sea

PHERETIMA—THE COMMON EARTHWORM

Earthworms live in damp soil but during the rainy season they come out and move freely on the ground. The body of an earthworm is long (10-20 cm) and cylindrical with 80-100 segments (Fig 35.1) In a fully developed animal there is a prominent circular band, the **clitellum,** occupying three segments (14 to 16) of the body All the segments except the first and the last bear tiny chitinous curved bristles (setae) which help in locomotion

A section across the body of an earthworm shows that it consists of two tubes placed one inside the other (Fig. 35 2) The outer tube is the body wall and the inner, the digestive tract. Between the two there is a spacious coelome which is filled with a fluid and is divided into a large number of compartments by transverse partitions corresponding to the external segmentation.

The earthworm swallows the soil by the action of its muscular pharynx. From here the soil passes into a grinding organ, the gizzard. The decaying bits of leaves along with the soil particles are finely crushed, and the whole mass passes into the intestine where the food material contained in it is digested and absorbed The undigested portion is passed out through the anus in the form of small balls or castings.

The vascular system is well-developed. The blood contains only white cells and the red pigment is dissolved in the plasma Respiration takes place by the exchange of gases through the skin which remains moist and is richly supplied with minute blood capillaries Excretion is carried out through special coiled tubes called nephridia which are present in large numbers in almost all the segments. The nervous system consists of a nerve ring surrounding the pharynx

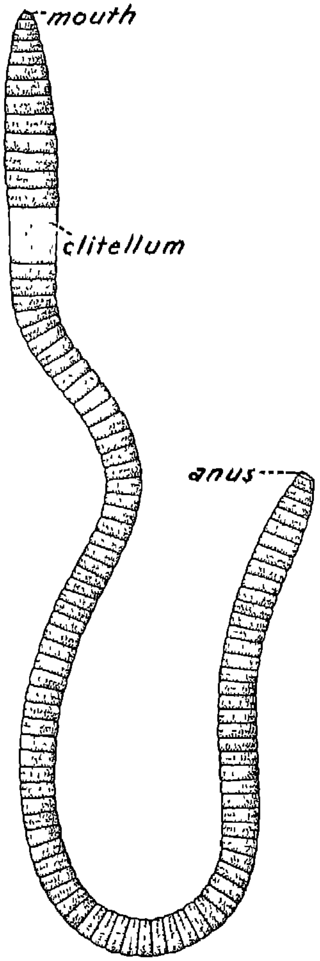

Fig. 35.1. **External features of an earthworm.**

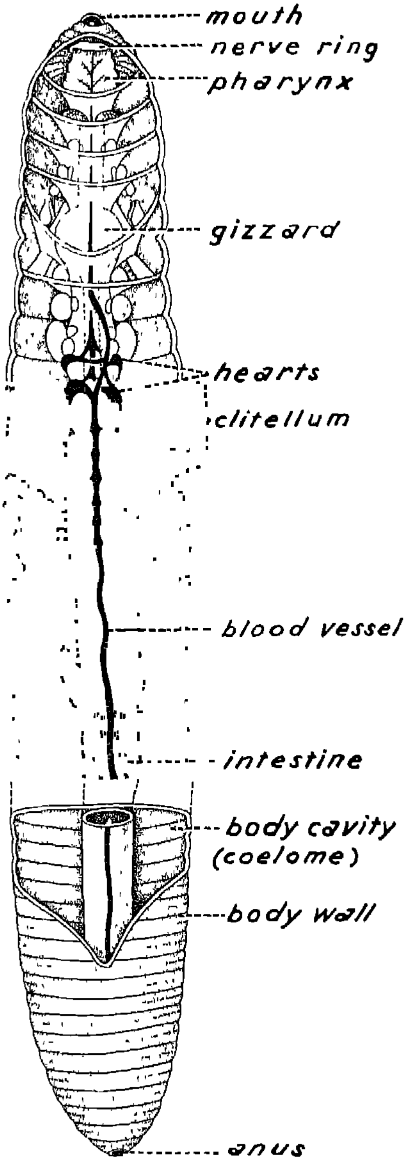

Fig. 35.2. **Diagram of a dissected earthworm showing some internal organs. The animal has been split open from the dorsal side.**

and a nerve cord which runs along the length of the worm below the digestive tract (Fig 35.2). In each segment the nerve cord forms a swelling (ganglion) from which the nerves are given off to the neighbouring parts. The earthworm has no special sense organs, but certain cells in the body wall are sensitive to the stimulus of touch. The anterior part of the body bears cells which are sensitive to light.

Earthworms are hermaphroditic but self-fertilization does not take place because the testes and ovaries do not mature at the same time. During copulation (Fig. 35.3) the sperms from one worm pass to the other and vice versa. At the time of egg laying, the clitellum secretes a covering (**cocoon**) which encloses the eggs (Fig. 35.4 A). The entire mass (the covering and the eggs) gets loosened from the body and is finally dropped in the soil (Fig. 35.4 B to E).

The earthworms possess a remarkable power of regeneration. If a worm is cut into two or three pieces, each of them can grow into a complete individual.

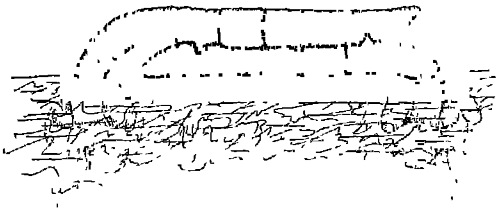

Fig. 35.3. Copulation in earthworm. During this process the anterior ends of the two earthworms protrude from the burrow and approach each other to lie together along the ventral sides. Exchange of sperms takes place through the reproductive openings.

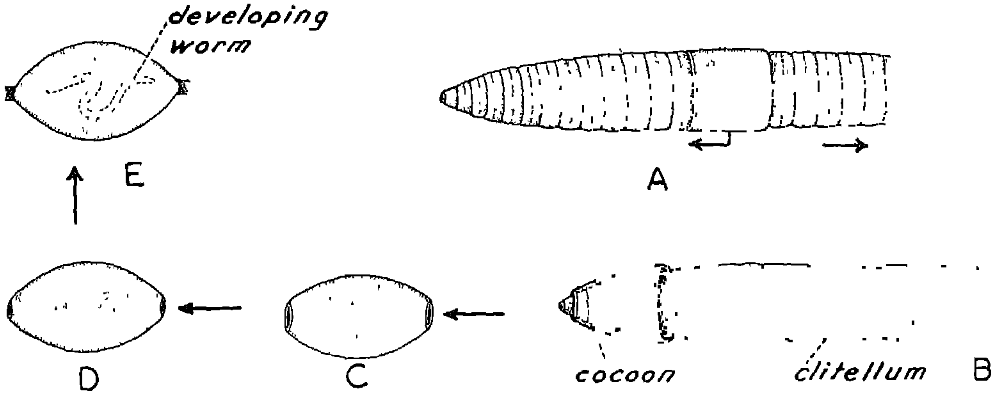

Fig. 35.4. Egg laying and fertilization in earthworm. The clitellum secretes a mucilaginous substance which hardens and forms a cocoon. This is pushed forward as the animal tries to slip out of it in the opposite direction. During this process, eggs and sperms pass into the cocoon from the respective reproductive openings. Only one worm develops in each cocoon.

Importance of Earthworm

Few people realize what an important role the earthworms play in agriculture. By their burrowing activity they loosen the soil, enabling the roots of the plants to grow deeper. Moreover, they continually churn the soil and bring its deeper layers to the surface. During digestion they grind the coarse soil into a fine powder and make it available in the form of their castings.

LEECHES—THE PARASITIC ANNELIDS

Leeches live in freshwater, in damp soil and in ponds where cattle wallow. When a leech wants to feed, it attaches itself to some animal (commonly cattle) and cuts into its skin with the help of its sharp jaws (Fig. 35.5). It then sucks the blood into its alimentary canal which is provided with a storage sac. Leeches are therefore regarded as external parasites. They were at one time used by village 'doctors' for removing the 'bad' blood from the wounds of their patients.

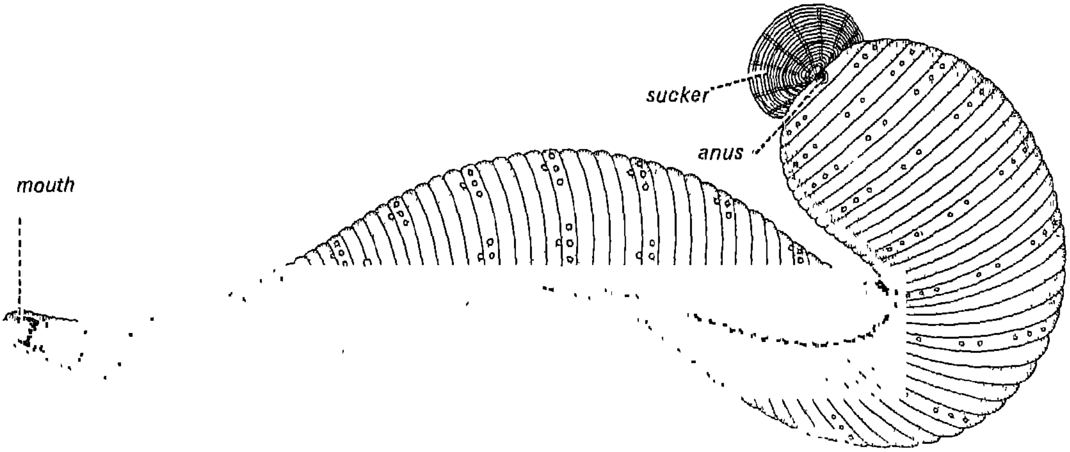

Fig. 35.5. The cattle leech (*Hirudinaria*). Its flat, elastic body is 5-10 cm long and dark or brownish-green in colour. It is seen more commonly during the rainy season in ponds or on damp soil.

SUMMARY

The annelids are worms with segmented bodies. There is a simple tubular alimentary canal which is modified in some cases according to the feeding habits of the animal The blood is contained in a series of special vessels Excretion occurs by means of nephridia.

The common earthworm, *Pheretima*, lives in moist soil Its cylindrical body is made up of 80 to 100 segments bearing setae on their ventral surface The setae help in locomotion. The body is built on the plan of tube within a tube The space between the two tubes is filled with coelomic fluid The earthworm feeds on the organic matter contained in the soil The soil is later passed out of the body in the form of small castings.

The blood vascular system is well-developed. The blood contains only white cells and the red pigment is dissolved in the plasma itself Gaseous exchange takes place through the skin. The nervous system is composed of a nerve ring, a nerve cord and nerve ganglia. Although the earthworm is hermaphroditic, fertilization of the eggs of one worm is always brought about by the sperms from another worm.

Earthworms play a significant role in agriculture since they make the soil loose and bring deeper layers to the surface. The leech is an external parasite, sucking the blood of cattle and man

QUESTIONS

1. What special features do you find in the digestive system of earthworm?
2. How is the blood of an earthworm different from your own?
3. The blood flowing out from a wound made by a leech does not clot easily. Explain
4. Why are earthworms often called 'Nature's ploughmen'?

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CHAPTER 36

Arthropoda— The Joint-Footed Animals

THIS is a very large and interesting group of animals containing a variety of forms such as cockroaches, spiders, crabs and centipedes. For a moment, you may feel that there is no common plan among these animals, but on a careful examination you will find that in each case the body has a tough protective covering (external skeleton) made of **chitin**—a horny flexible substance. In most forms the body is segmented and the limbs have several conspicuous joints, hence the name Arthropoda (Gk *arthron* = joint, *podos*=foot).

The arthropods constitute more than three-fourths of the total number of species under the animal kingdom. They are found in every part of the world and in every environment. Some of them are useful to us while others are very injurious. We can divide the arthropods into four major classes: prawn group (Crustacea); centipede group (Myriapoda); spider group (Arachnida) and the insect group (Insecta or Hexapoda)

Crustacea

Prawns, crayfishes, lobsters, crabs, and water fleas are the common examples of Crustacea They all have a crust-like outer skeleton which is cast off and regrown periodically to accommodate the growing body This process is called **moulting.** The segmented body shows three regions· the head, thorax and abdomen. The first two regions are usually fused together to form a **cephalothorax** which bears two pairs of long feelers.

Most of you must have seen the common Indian prawn (Fig 36.1) which is a favourite food of many people It is found in freshwater lakes or in estuaries. It has an elongated body. The cephalothorax is covered by a large shield and the eyes are situated on movable stalks Each eye is composed of numerous small units and is therefore described as compound The abdomen is somewhat bent and carries a pointed tail-piece. There is a series of paired appendages which differ from each other in their location and function

The crayfishes and lobsters (Fig. 36.1) are similar to the prawn. The crayfishes live in freshwater whereas the lobster is marine. Many of them are edible

Crabs (Fig. 36 2) have broad bodies and strong claws. The body is well-protected under a shell-like covering and some types

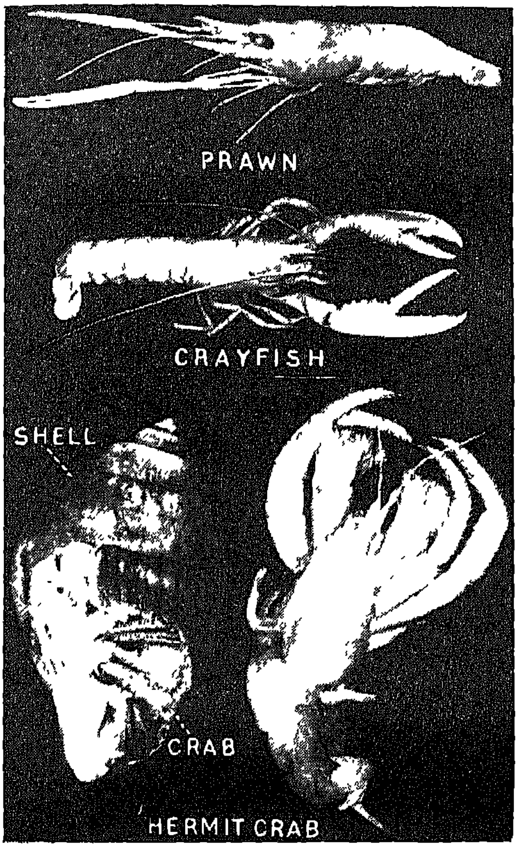


Fig. 36.1. Some of the common large crustaceans.

are beautifully coloured. The short abdomen is closely bent under the cephalothorax. A very interesting thing is that the crabs walk sideways instead of keeping the head in front. Some live inside the empty shells of sea snails. These are called the hermit crabs (Fig 36.1) which carry their 'house' wherever they move

Certain crustaceans are very small A drop of stagnant water from a pond would usually show several microscopic forms. The commonest among these are the water fleas—*Daphnia* and *Cyclops* (Fig. 36.3). If you observe a living *Daphnia* under a microscope, its pulsating heart is clearly visible through the transparent covering *Cyclops* has an elongated body and a forked tail Its female usually carries a pair of egg sacs near the hind end of the body. These organisms form an important fish-feed

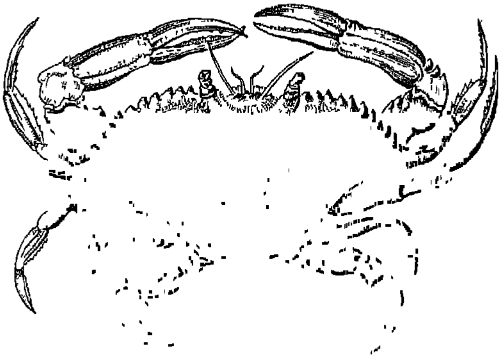


Fig. 36.2. The true crab. Note the eyes borne on long stalks.

Myriapoda (Many-Legged Animals)

This class includes the millipedes and centipedes (Fig. 36.4). The millipedes are specially common in the rainy season. You may have seen them as dark-grey, worm-like cylindrical creatures, about 2-3 cm long, and crawling freely in gardens They frequent damp soil under stones and logs. When you touch a millipede it rolls up its body. Have you ever tried to count the number of 'legs' it has? They are not as many as a thousand as implied by the name millipede (L. *mille*=a thousand, *podos* =foot) but only about a hundred pairs Each of the visible body segments is actually made up of two fused segments, and so there appear to be two pairs of legs on each segment. For this reason these animals are called the Diplopoda, or 'double-footed animals'. There

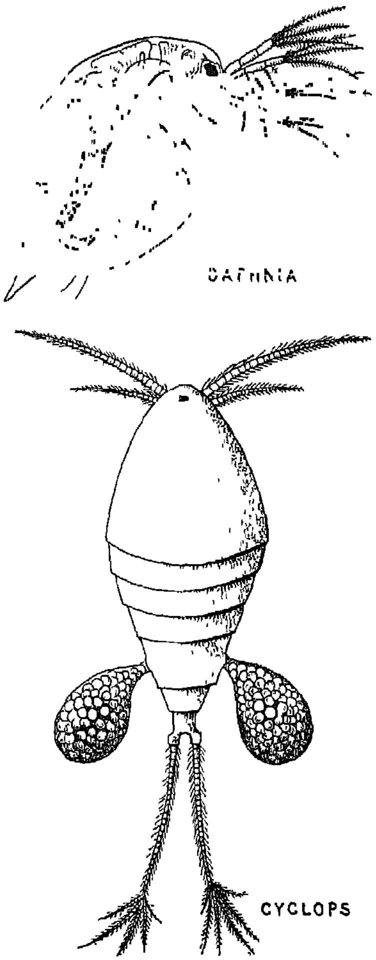


Fig. 36.3. Two small crustaceans, the water fleas. They form an important food of fish.

are numerous species of millipedes spread throughout the world. Some are large and have about 200 pairs of legs. All millipedes are slow-moving, harmless animals. They feed on vegetable matter.

The centipedes have a slightly flattened body consisting of 15 to 100 segments, each except the last two bearing a pair of legs. The head bears a pair of feelers and a pair of poison claws which are used to kill small animals. The centipedes run fast and are usually difficult to catch. One species is about 15 cm long and is commonly called 'kankhajura' in North India It is so named because there is a widespread but false belief that this centipede would enter the ears of sleeping persons.

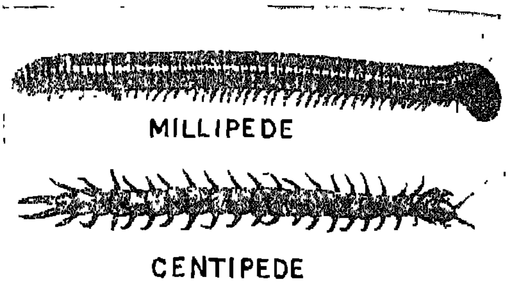


Fig. 36.4. The arthropods with many legs. Due to their fast movement they appear as having many more legs than they actually have.

Arachnida (Spiders and Their Relatives)

Spiders, scorpions, ticks and mites (Fig 36.5) are common examples of this class. They are found mostly on land but some occur even in the sea. Most ticks and mites are parasites. You can recognize the arachnids by the presence of four pairs of legs. In addition they have two large pedipalpi and a pair of chelicerae close to the mouth as in the scorpions. The head and thorax are fused to form a cephalothorax. The eyes, when present, are simple.

The scorpions are very common everywhere There are numerous species in India and some are very poisonous. The poison is secreted from a gland situated at the swollen tip of the abdomen which is

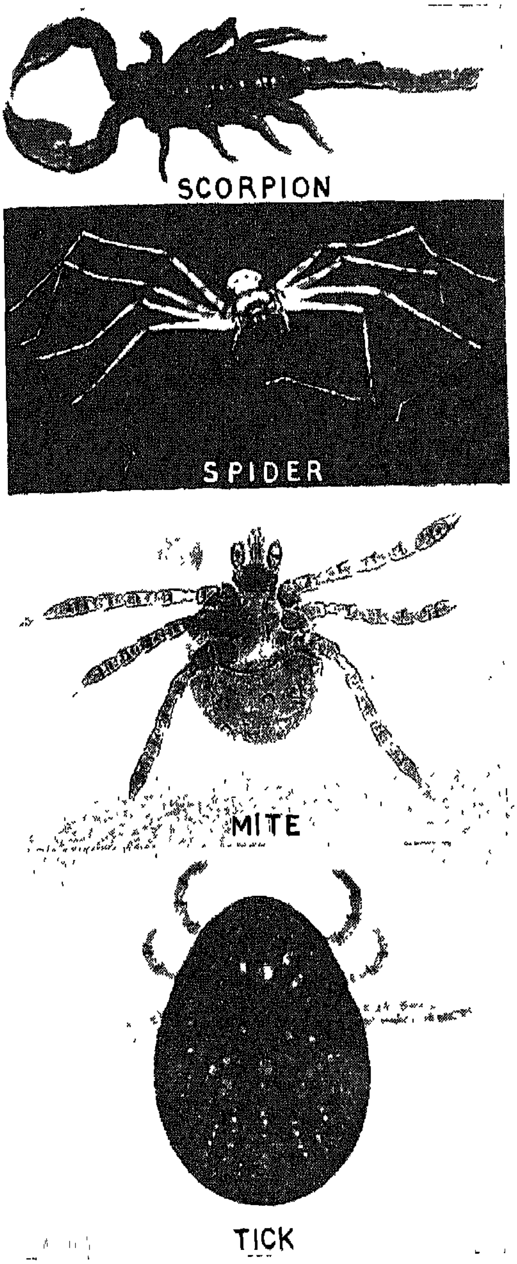


Fig. 36.5. Some common arachnids. The scorpion has a sting at the tip of its abdomen. The tick and mite differ from other arachnids in that in their bodies the usual division into cephalothorax and abdomen is not distinct.

somewhat curved upwards. This sharply pointed sting is used to inject the poison into a victim. The huge forwardly projecting pedipalpi, although frightful to look at, have no poison. These are used only for catching the prey. Unlike most arthropods the scorpions give birth to young ones (viviparous).

The spiders are quite common in houses, gardens and on the trees. Most of them weave a kind of web which is used for trapping small insects or other prey. The web is spun from a fluid produced in the silk glands present in the swollen, hind region of the body. The fluid is poured out through three pairs of fine, finger-like **spinnerets** situated on the underside of the body. The fluid is ejected under high pressure through the spinnerets and it instantly hardens to form a thread. When an insect happens to sit on the web, the vibrations reach the spider. It then comes out of the web and entangles the victim by quickly spinning sticky threads round its body. The captured prey labours in vain to escape and is soon suffocated to death. The spider sucks the juice from the dead insect's body leaving its skeleton hanging in the web. Some spiders, such as the wolf spider, do not spin webs but produce only a single thread for suspension. Others have a poison gland also. The class name Arachnida (Gk. *arachne* = spider) is actually due to the spinning activity of the spiders. In Greek mythology, Arachne was an expert spinner even surpassing Minerva (goddess of wisdom) in this art. The story goes that in anger the goddess turned Arachne into a spider.

The ticks and mites are often parasites on man and other animals. Mites are usually very tiny, even microscopic. One mite, called the itch mite (causing common itch or scabies), lives on the human skin and burrows beneath to lay eggs. The itching sensation is produced when the young mites start moving in all directions. Another species causes similar disease in dogs and cattle. Some mites also live on plants. The ticks are larger than mites and have somewhat swollen bodies. You can easily find many ticks on the bodies of cattle and dogs, sticking chiefly to their ears where they keep on sucking the blood. Some may occur even on man and spread certain diseases. A few ticks are free-living, such as the beautiful, red and velvety types commonly seen during rains. In mites and ticks the body is not divided into any segments or regions externally (Fig 36.5).

Insecta

The word 'insect' is very familiar to you You often use this name for any small creature you come across, but a true insect is one which has three pairs of jointed legs and whose body is divided into three regions—the head, thorax and abdomen (Fig 36.6). Usually it has two pairs of wings The head bears a pair of long feelers or **antennae**, a pair of compound eyes, and a set of mouth parts enclosing the mouth opening. The mouth parts are modified according to the feeding habits of the insect They may be of the biting, piercing or sucking type.

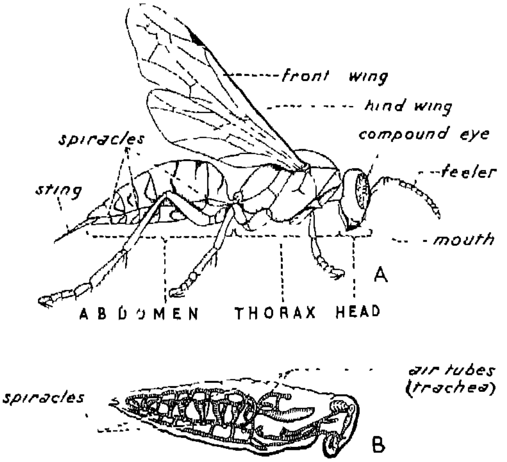


Fig. 36.6. Body parts of an insect. A. Important external divisions and parts of wasp, a common insect. B. The spiracles and respiratory tubes of an insect. Courtesy of S.S. Sehgal, Department of Zoology, University of Delhi

There are about a million species of insects. They are found in all countries and in all climates—on snow-covered mountains, in torrential streams, in lakes and seas, in hot deserts, on or around vegetation of all types, and in stored grains Quite a few live as parasites on man, cattle and other animals. In fact, the insects are most remarkably adapted to live under varied conditions.

When viewed with a magnifying glass the eyes show a very large number of little hexagonal areas or facets (Fig 36.7). Each facet is a transparent lens that focuses the rays of light on a sensitive structure comparable to the retina of the human eye. The object is viewed in as many bits of image as the number of facets. Such a vision is called **mosaic vision.** The middle region of the body or thorax consists of three segments each carrying a pair of legs. The

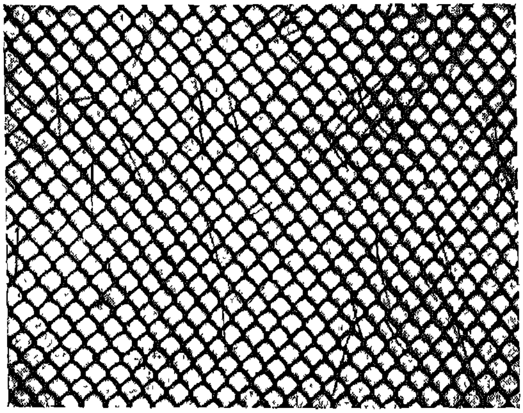


Fig. 36.7. Surface view of an insect's eye. Each six-sided area represents a facet. The images formed by such a collection of facets produce the mosaic vision.

last two segments usually bear two pairs of wings

The abdomen is usually concealed below the wings. It does not bear any legs. A series of small paired openings, the **spiracles**, are present on the thoracic and abdominal segments. These openings lead into a large branching system of fine tubes, called **tracheae** which extend to all parts of the body (Fig, 36.6 B). The tubes constitute the respiratory system of the insect. Air enters and leaves through the spiracles after circulating in the entire body.

Life history of a housefly. *Musca domestica* is the name of our common housefly. Its legs have claws and spines which enable it to cling even to such smooth objects as window panes If you watch a living fly, you will often find it cleaning its legs by rubbing one over the other

The female lays about 100 eggs at a time in cowdung, horse manure and other putrefying organic matter. It does so five or six times during summer months The eggs are whitish and somewhat elongated In about 12 hours they hatch into larvae called **maggots** (Fig 36 8). The maggot has neither head nor legs, and looks like a little worm. It feeds on decaying organic matter, and grows by moulting. After about five days it contracts its body and changes into a dark brown barrel-shaped **pupa.** Within a week the pupa develops into a fly which breaks open its covering or cocoon. It takes about two weeks to complete its life history from egg to adult. When a fly is about two weeks old it is ready to mate and produce the next generation.

The housefly transmits the germs of various diseases such as cholera, dysentery and typhoid. It visits all types of refuse from where the disease germs stick to its legs When it happens to sit on food this becomes contaminated. Eating such food may cause severe illness

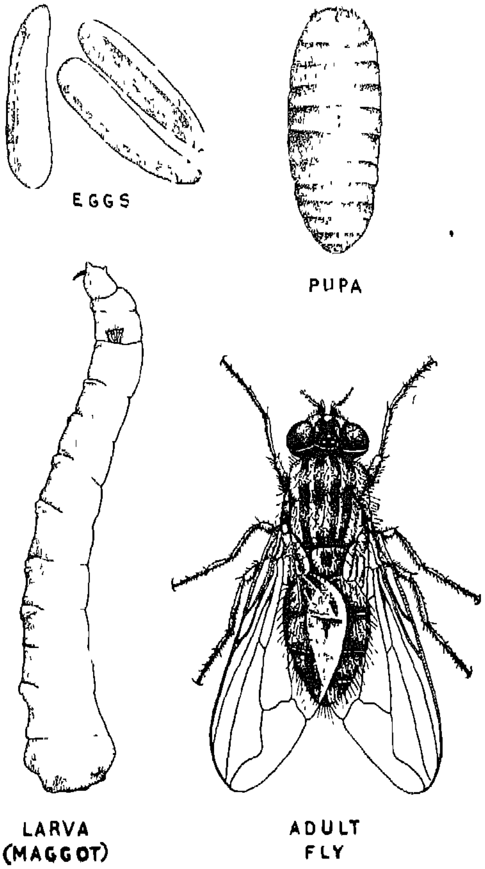


Fig. 36.8. Stages in the life history of a housefly. From an egg to an adult fly is a matter of about two weeks only.

Life history of a mosquito. There are two common genera of mosquitoes—the malaria-spreading *Anopheles*, and elephantiasis-spreading *Culex*. With the efforts of health organizations malaria has been greatly reduced, and attempts are now being made to eradicate elephantiasis

The two types of mosquitoes can be easily recognized by their resting postures

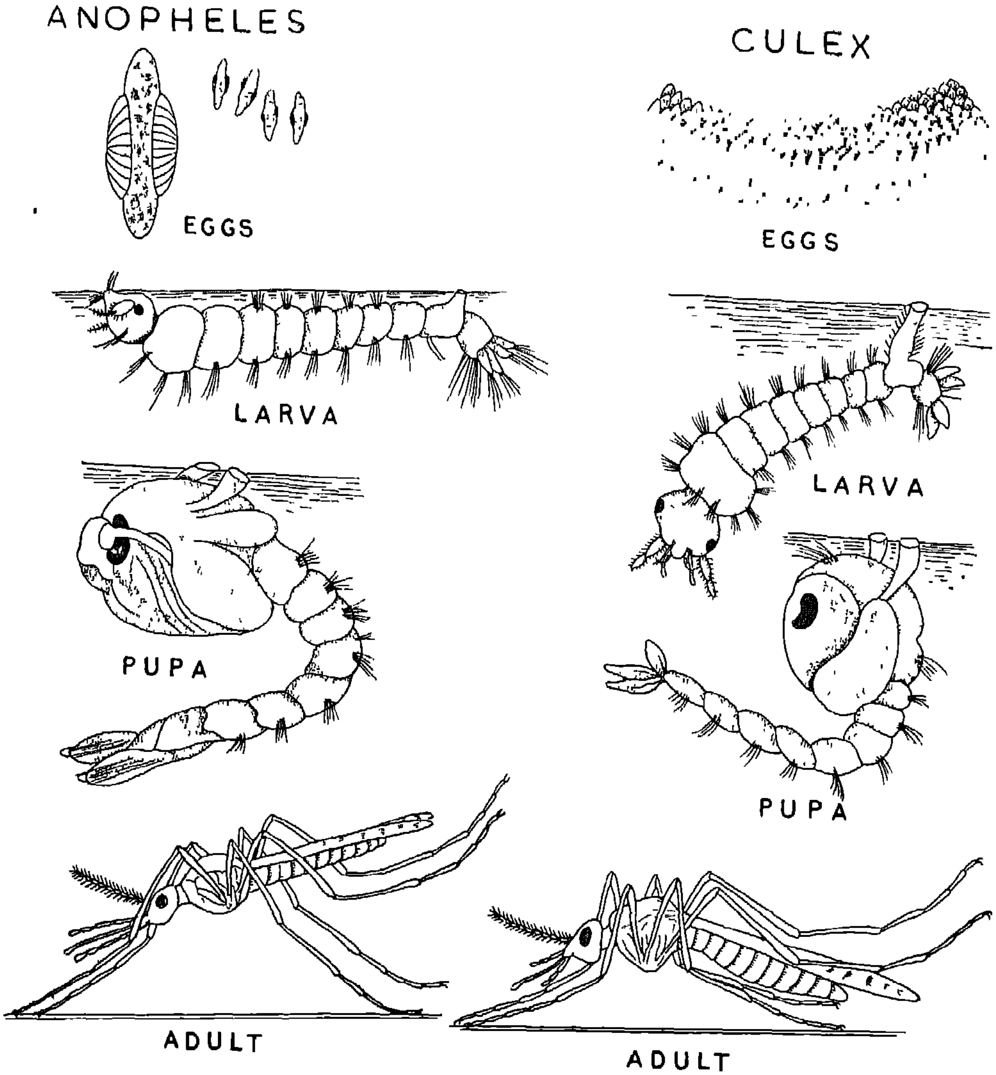


Fig. 36.9. Stages in the life histories of the two kinds of mosquito.

(Fig. 36.9) *Culex* keeps its body parallel to the surface whereas *Anopheles* keeps it at an angle The female mosquitoes have piercing and sucking mouth parts. The males do not have any piercing mouth parts and can only suck exposed liquids.

The mosquitoes lay their eggs in stagnant water. The various stages in the life cycle of the two mosquitoes are quite distinct. In *Culex* the eggs are deposited in tiny rafts which float on the surface of water; in *Anopheles* they are laid singly (Fig.36. 9). Each egg has a small air space to keep it afloat. In about three days the eggs hatch into transparent larvae which swim actively in water and come up to the surface from time to time to breathe atmospheric air.

They bear a respiratory tube at the tail end While afloat the culex larva hangs head downwards, but the anopheles larva keeps almost horizontal. The larvae feed on aquatic plants and increase in size. In about two weeks the larva changes into a pupa It has a large body in which appear the rudiments of the head, eyes, antennae, wings and legs There are two respiratory tubes on the thorax The pupae of the two mosquitoes are almost similar, but the respiratory tubes of anopheles pupa are shorter and wider The pupa does not take any food. If disturbed, it quickly moves deeper and rises again to rest on the surface. In a few days the pupal skin splits and the adult, winged mosquito or **imago** is released.

Metamorphosis in Insects

In the life history of the housefly and mosquito, you have seen that the animal hatched from the egg (larva) is appreciably different from the adult and it has to pass through a series of stages before attaining its adult form The entire process is called **metamorphosis** and is seen in most insects This process takes place by moulting or a repeated casting off of the 'skin'. Moulting allows an increase in size during growth; the cuticle by itself is a rigid covering on the body and would not permit any increase in size. As one stage is completed, the cuticle becomes thin and weakened and is thrown off Meanwhile a new cuticle is laid and after a certain increase in the size of the insect this too gets hardened. The process may be repeated a number of times and the number of moults is fixed for the different species. Once the adult size is reached no further moulting takes place.

In the development of other insects like cockroach, the young one hatching out of the egg is similar to the adult insect, except that it lacks wings and certain other organs After the first moult the rudiments of the wings appear and in the successive moults they gradually increase in size. This is accompanied by the development of the other organs such as gonads Similar changes are noticed in the grasshopper, bed bug and dragonfly In all these the immature stage essentially resembles the adult and is called the **nymph** Thus there are three stages (a) the egg, (b) the nymph and (c) the adult. This kind of metamorphosis is called the **incomplete** or **gradual metamorphosis.**

On the other hand, in the mosquito, housefly, butterfly or silk moth the young one that hatches from the egg is very different from the adult, both in structure and mode of life The caterpillar of a butterfly, for example, has numerous legs. It also has powerful jaws and bites and chews the solid food material. The adult butterfly is quite different in shape; it has no jaws and only sucks nectar or sap from plants Similarly, the mosquito larva is entirely different from the adult mosquito When full grown, the larva changes into a pupa which is generally inactive and does not take any food. The pupa undergoes some drastic changes—the larval organs are lost and the characteristics of an adult are developed. A metamorphosis involving all four stages—egg, larva, pupa and adult—is called **complete metamorphosis.**

In certain insects like the silverfish, the young one completely resembles the adult except in size. Their life history obviously involves no metamorphosis

Economic Importance of Insects

Insects influence our life in many ways. Most of them do us serious harm but a few are very useful. Man is constantly at war with the former in practically every sphere of his life.

Harmful insects. There is a large number of insects which cause either direct injury or bring agents of various diseases to man and livestock The mosquitoes bring malaria, elephantiasis, and yellow fever. The housefly spreads the 'germs' of dysentery, cholera, trachoma and many other diseases The sandfly is responsible for kala-azar The tsetse fly brings sleeping sickness and the ratflea (Fig 36.10) spreads bubonic plague. Insects spread scores of diseases in horses, cattle, sheep and chicken Most of these are blood-sucking types which transport disease germs from infected to healthy individuals Every year, throughout the world, thousands of people and a vast number of livestock die due to disease-transmitting insects. And even for those people who survive the attack of these diseases, it is difficult to make an estimate of the loss of working time, efficiency and money. Insect pests of livestock lower the production of meat and milk and the quality of hides Municipalities all over the world spend much time and money in combating such insects.

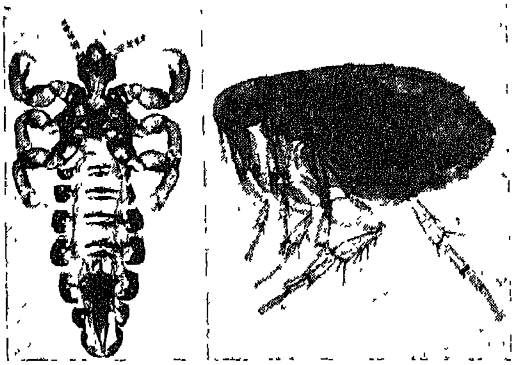


Fig. 36.10. The body louse (left) and rat flea (right) are ectoparasitic insects.

Some insects cause a good deal of pain and injury without seriously endangering our lives. You must all be familiar with the painful stings of bees and wasps, the annoying bites of ants and the big blisters caused by the blister beetle. The body lice (Fig. 36.10) and head lice produce an irritating tickling sensation by crawling over the skin. They also spread the germs of typhus The termites or white ants cause untold destruction of furniture, books, paper, carpets and so on The crickets and silverfish may bite through paper and starched garments The larvae of the clothes moth and of the carpet beetle destroy fur, carpets and woollen garments Ants, flies and weevils spoil many articles of food. Cockroaches present an ugly sight and spoil our eatables.

Our worst insect enemies are those which destroy crops, vegetables, fruits, and forests. The damage caused by these insects runs into millions of rupees every year There is virtually no plant which is not attacked by one or the other type of insect. The most notorious among the insect enemies of crops are the locusts They have figured prominently in the history of mankind and have often led to famines in many parts of the world India has about six different types of locusts and the most harmful is the desert locust which moves in gigantic swarms It affects practically the whole of northern and central India. Wherever a locust swarm settles on a crop, it reduces the vegetation to bare twigs The Plant Protection Department, through its various units in different states, is expected to take all possible measures to control our crop pests

The stored grains are attacked by many kinds of moths, caterpillars and beetles. Any old sample of improperly stored rice or wheat would show certain weevils and their larval stages

Numerous moths, beetles, bugs and termites are a constant menace to the forest trees

Useful insects. These serve us both directly and indirectly The beetles, ants and their larvae improve the condition of the soil by their burrowing activities Ants, termites and other minute insects are constantly at work destroying dead leaves, twigs and trunks, and enriching the soil by providing nutrients for plant growth. Some insects like the dung beetle and the carrion eaters hasten the decay of animal wastes and dead bodies. Others are useful predators, i.e they feed upon and destroy many injurious forms Thus the larvae of certain lady-bird beetles and hoverflies are effective destroyers of aphids The dragonflies and damselflies devour certain other flies The praying mantis voraciously eats certain crop pests including small grasshoppers and caterpillars A kind of blister beetle devours the eggs of locusts by entering their egg capsules in the soil

A number of insects live as parasites on the bodies of larvae and the adults of many harmful forms This acts as a check on the outbreak of pest epidemics Scientists at the agricultural stations in many parts of the world are developing suitable strains of these parasites and keep them ready for use in the fields to combat a particular pest This kind of practice of controlling the pest by a parasite or a natural enemy is called **biological control**, and has proved to be quite effective

The role of insects as pollinating agents is well-known. You have already read in Chapter 15 how various insects such as bees, moths and butterflies are indispensable for the pollination of certain crops. Many insects including the butterflies and moths are very beautiful and their collection and preservation is not only a rewarding scientific study but also a fascinating hobby. During the last few decades insects have been extensively used in scientific experiments. The most classic studies on the mechanism of heredity are those performed on the well-known fruitfly *Drosophila*

Lastly, some insects are of commercial importance These have provided means of livelihood to hundreds of thousands of people all through the centuries and are doing so even today They have made a valuable contribution to human food and clothing and provided other useful products

The honey bees provide us with honey and beeswax These insects live in large social colonies A good colony comprises more than 90 per cent (60,000 or more) workers Every worker has two important tools, a nectar-collecting tongue on its head and a pollen-collecting basket on its hind legs. According to one estimate, about 1,000,000 loads of nectar are required to make a kilogram of honey The nectar is collected from flowers and is brought to the nest by the worker bees in their honey stomachs Before the nectar is stored in the cells of the hive it is acted upon by certain enzymes of the bee saliva. As a result, the cane sugar of the nectar is converted into fruit sugar. After it is deposited in the cells, the nectar, now called honey, is thickened by the fanning of the wings and is finally sealed up for preservation The honey is a very delicious and nutritive food. Historical records show that honey was the first sweetening agent used by man The use of sugar is more recent

The beehive is made up of beeswax which is produced as thin flakes or scales from the glands on the underside of the abdomen of the worker bees Beeswax is used in industry and art

Silk comes from the cocoons of silkworm moths. Of these mulberry silk is supposed to be the best and is produced by the caterpillar of the moth *Bombyx mori*. This silk has been known to mankind for more than 2,000 years. Throughout these centuries man has taken so much care of the moth that it has ceased to exist in wild form and is now entirely domesticated. It feeds on mulberry leaves. When full grown, the larva spins a cocoon. The cocoon is formed from a secretion of two large glands extending throughout the interior of the body. As the viscous fluid is poured out and exposed to the air, it hardens into a fine silk fibre. During spinning the caterpillar moves its head from side to side and goes on adding the thread in the form of a case. It takes nearly three days to complete a cocoon. A single cocoon contains nearly 800 metres of the silk fibre. Normally in about two weeks the moth cuts through the cocoon (Fig. 36.11).

In the commercial reeling of silk the cocoons are gathered about one week after the spinning begins. The pupae are killed by immersion in boiling water. The filaments from four or five cocoons are twisted into a thread and wound on a reel. India, China and Japan are the largest natural silk producing countries. Silk production is a very highly developed industry in Kashmir, Mysore and Assam.

The lac insect is a very tiny form living on twigs of certain trees like 'palas', 'peepal' and 'ber'. In India its maximum cultivation is done in Bihar. The insects remain sticking to the twigs and secrete a resinous material which ultimately covers them all over. The branches become thickly covered with such encrustations. The lac is harvested from time to time and used for making gramophone discs, insulation material for electrical goods, toys, bangles and a variety of other things. Lac is also the source of a red dye used in paints and polishes.

Another red dye, 'cochineal', is obtained from an insect related to the lac insect. It lives on certain cacti. The dye is used for colouring cosmetics and beverages.

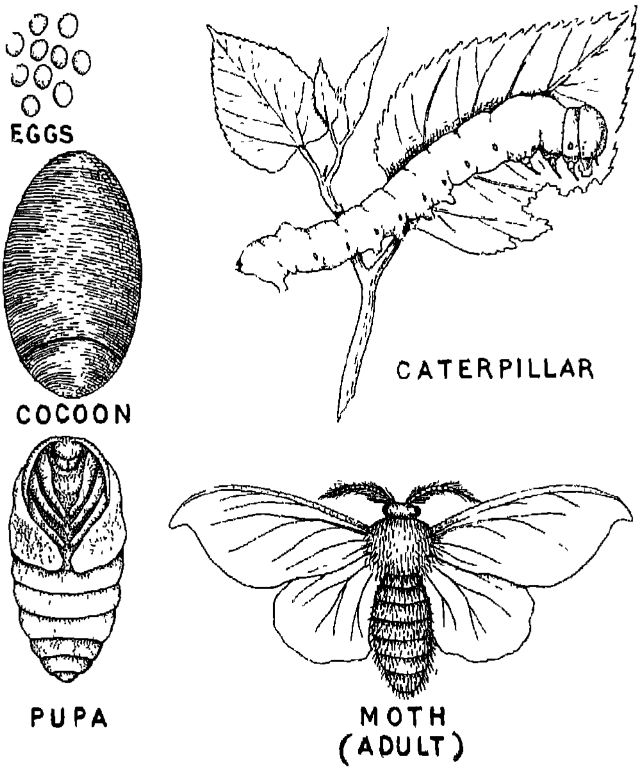


Fig. 36.11. Stages in the life history of the silkworm moth. Two weeks after the spinning begins, the pupae mature into adult moths and cut through the cocoon.

Social Life in Insects

The bees, ants, some kinds of wasps and termites live in highly organized societies. They always build some kind of a nest. The colonies may consist of a few to thousands of individuals living a perfect disciplined life. There is a division of labour and different castes are well established

A honey bee colony, often with more than 50,000 members is headed by a single fertile queen (Fig. 36. 12). In a flourishing colony a new queen is produced among the progeny On emergence from her cell, this new queen generally kills the other queen-destined larvae and also sometimes the old one, i.e its mother. After a few days, this new queen undertakes a short flight. A few hundred drones (males), who ordinarily do no work, become active and chase the queen One of them mates with her and deposits sperms in her body. With just one mating the queen stores sperms enough for her lifetime (about 4-5 years). The workers (sterile females) constitute more than 90 per cent of the population of the colony. They do all the work from nest-building to 'child-care' and feeding the queen. The workers returning from the fields perform peculiar dances to indicate to the other members of the hive the direction and distance of the food source. Members of each hive recognize each other not by vision but by smell, and do not tolerate any intruder. Sex and caste determination in bees is very interesting The unfertilized eggs produce male larvae developing into drones. The fertilized eggs produce female larvae which are capable of growing into workers or queens. Larvae given a rich food (royal jelly secreted by the nursing adult workers) become queens while those fed on honey and pollen develop into workers.

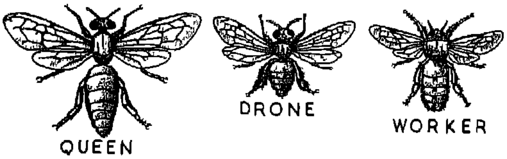


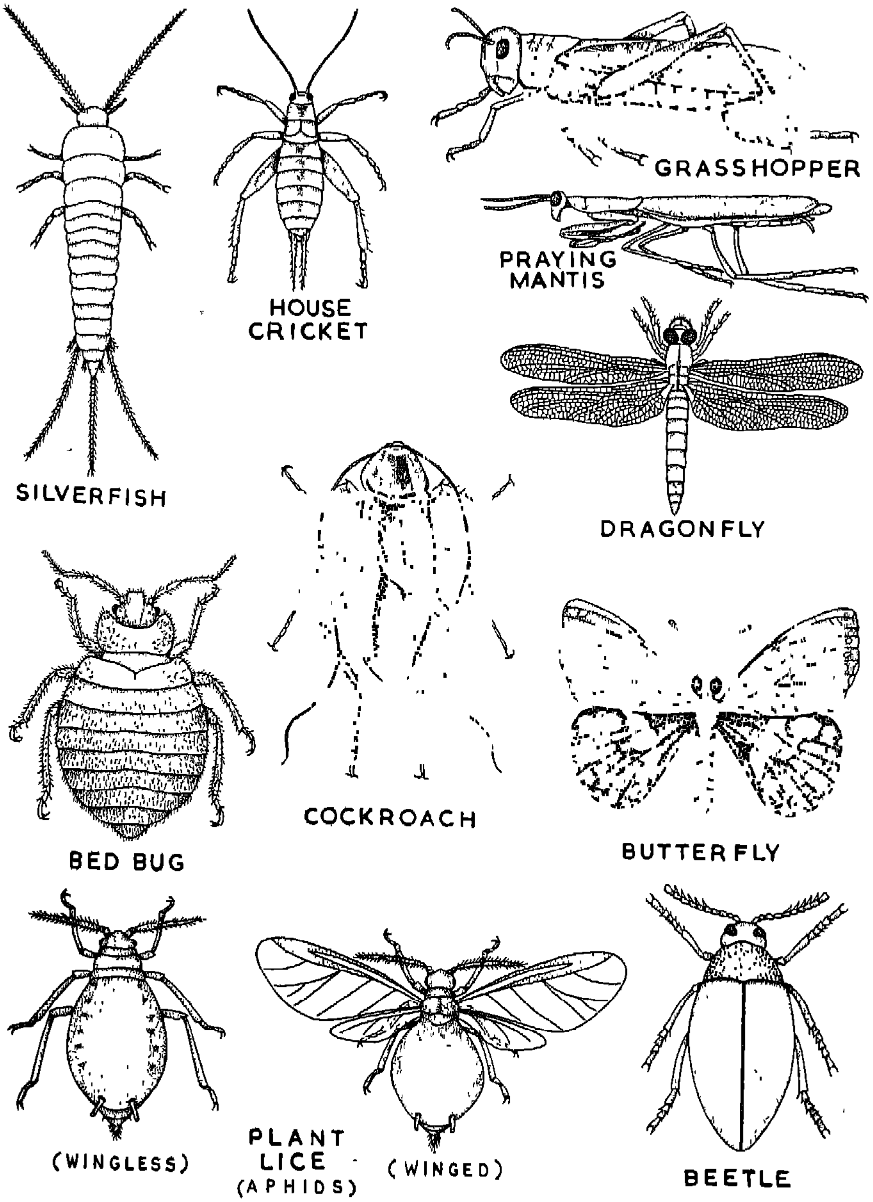
Fig. 36.12. The three castes of honey bee.

In ants there may be one or more queens in a single nest The workers are sterile females which do most of the work. Certain strong and large workers that guard the colony are known as soldiers. All the members of an ant colony are normally wingless. During rains, however, winged ants (males as well as females) are produced which come out of the nest and fly. After pairing they drop their wings and the female starts a new colony or joins some old one. The sense of smell is very strong in ants. They establish odour (smell) paths with the help of some scent from their body. You can easily see the ants moving along a definite line on the ground or on the walls.

The termites (Fig. 36 14) also have well-organized colonies consisting of a king, a queen, workers and soldiers. Each colony ususally has one royal pair—the king and the queen—which possess wings only in their early life. The workers are sterile, wingless and blind. They may be male or female. The soldiers have powerful jaws and may be of either sex Every rainy season, perfect winged males and females are produced which swarm near the lights They mate and shed their wings They bore holes into the soil and start a new colony To start with, the young ones produced from them are all workers and soldiers. The queen increases in size with the advance of age, whereas the king remains unchanged.

Some Common Insects

To give a complete picture of the strange ways of insects would require many volumes bigger than the size of this book. You can introduce yourself to some interesting insects by studying figure 36.13.



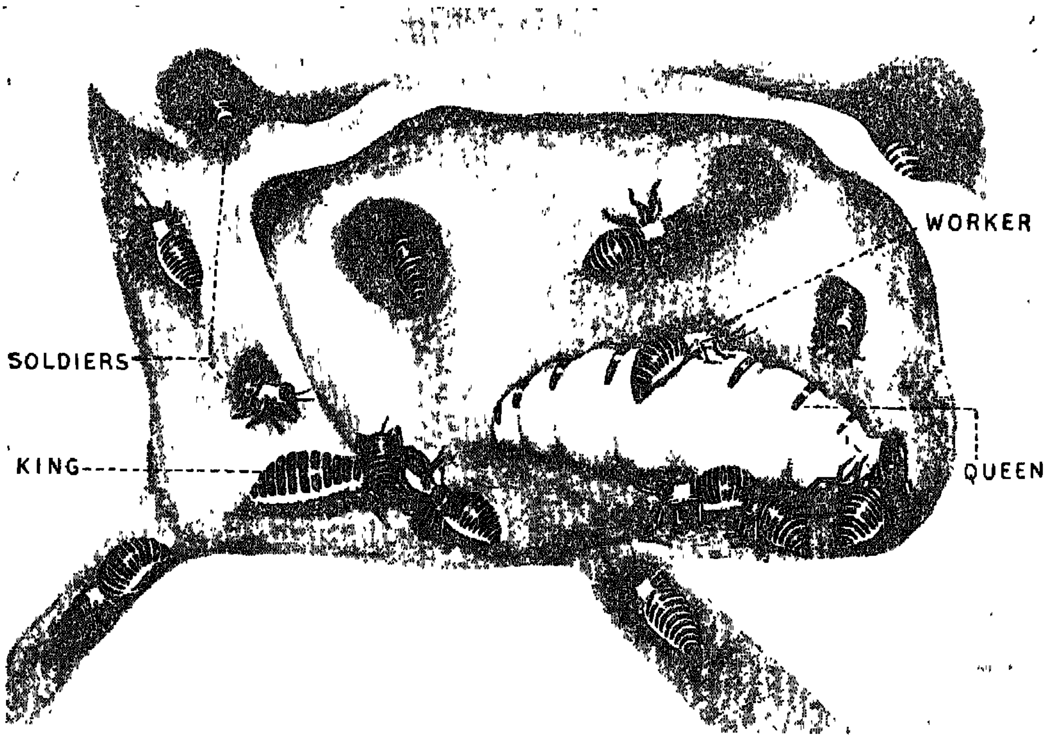


Fig. 36.14. A termite nest. The queen has her own chamber, note her large abdomen. The king is much smaller. The soldier has a pointed head that can discharge poisonous chemicals. From *BSCS, Molecules to Man*, Houghton Mifflin Company, Boston, 1963

Fig. 36.13. Some insects. The silverfish is a fast moving, wingless, silvery insect common in cup-boards and book-shelves. It is fond of starchy food. The house cricket makes the familiar chirping noise in dark corners. With its chewing mouth parts the grasshopper eats away the leaves of crops, causing much damage. While at rest its front leathery wings cover the large and membranous hind-wings. It can also take a long jump with its third pair of long legs. The praying mantis holds its front legs as though offering a prayer. Although it owes its name to this attitude of prayer, its habits are brutal. With its strong jaws it can easily cut off the head of a grasshopper. The dragonfly with its long, slender body keeps its large membranous wings stretched even while resting. The bed bug lacks wings though most bugs have two pairs of these. It has piercing mouth parts which form a tube. With these it punctures the skin and sucks the blood. The plant lice or aphids are tiny, greenish or greyish insects found on leaves of many crop plants. They too have piercing mouth parts with which they suck the sap of the leaves. The cockroach is quite common in the dark nooks and corners of dingy houses. It keeps moving its pair of long feelers to sense its surroundings by touch and by smell. The butterflies are familiar colourful insects seen in the gardens. The colouration of their wings is due to the presence of numerous tiny scales. The powdery stuff that comes off on your hand when you catch a butterfly really consists of these scales. The beetle has shell-like front wings fitting tightly over the body and concealing the thin membranous second pair of wings. The weevils that destroy the stored food grains, and glow-worms as well as fireflies are also examples of beetles. The drawings are not proportional to the actual sizes of the insects.

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SUMMARY

The arthropods constitute the largest phylum. They comprise nearly three-fourths of the entire animal world. The most distinguishing characters of the arthropods are. segmented body, cuticular covering over the body wall and jointed legs The number of legs helps in identifying the various classes

The crustacea are mostly aquatic forms Most of them breathe by means of gills. Some crustaceans, such as crayfishes and crabs are valuable human food. Some microscopic crustaceans form the food for fishes.

The myriapods are terrestrial arthropods having a fairly large number of legs. The centipedes have one pair of legs to each body segment whereas the millipedes have two pairs.

The arachnids are recognized by four pairs of legs and a pair of pedipalpi. The scorpions and some spiders have poison glands in them.

Insects show the widest range of habit They have three pairs of legs and usually two pairs of wings A large number of insects are harmful They destroy our standing crops, stored food as well as other articles, and spread diseases in man and animals. The honey bee, lac insect and silkworm yield valuable products. Moths, butterflies and bees render a valuable service by pollinating the flowers of many crop plants. The bees, ants and termites lead a remarkable social_life.

QUESTIONS

1. How would you distinguish an arthropod from other animals?
2. What is the difference between a centipede and a millipede?
3. Where is the sting of a scorpion located?
4. What type of respiratory organs are found in insects? In what principal way does respiration in an insect differ from that in man?
5. Name three insects of commercial importance in India.
6. Where would you look for to find stages in the life history of housefly and mosquito?
7. Which caste of bees visits flowers ?
8. What is the function of winged ants and termites?
9. Which is superior: the exoskeleton of arthropods or the internal skeleton of vertebrates? Explain.
10. Certain insects never produce any offspring. Reproduction being one of the important differences between the living and the non-living, how can you consider these animals as living?
11. Some insects are said to have a grandfather but no father. Explain how this is possible.

12 How can you distinguish a spider from an insect?

13 Write short notes on (a) nymph, (b) larva, (c) pupa, and (d) cocoon.

14. How do ants find their way back to their nests?

15. How do you think the bees and other insects have learned to live so harmoniously in a colony ?

16. How do you designate the scientists who study insects?

17 Some people still believe that flies develop from dirt, and mosquitoes from foul water. How do such beliefs come about?

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CHAPTER 37

Echinodermata— The Spiny-Skinned Animals

THE echinoderms are radially symmetrical marine animals with a spiny skin. The body is unsegmented and star- or ball-like. There is no head. The mouth lies on the under surface of the body and the anus is usually situated at the opposite end.

The starfish (*Pentaceros*) is a very common echinoderm around our coast in shallow waters It has a star-shaped body with a central disc and five radiating arms (Fig 37. 1 A) . The mouth lies in the centre of the flat lower surface and the anus on the upper surface of the disc. The body is covered with spines joined basally with calcareous plates imbedded in the skin On the lower surface of each arm is a groove containing fleshy tube feet (Fig. 37.1 B) which can be pushed in and out by the pressure of water pumped into them from a system of water vessels running throughout the body. The tube feet help the animal to crawl. The starfish eats worms, clams and oysters. When it finds a clam, it holds the animal with its tube feet and pulls the two shells apart At the same time it secretes a substance which relaxes the powerful shell-muscles The stomach is then turned inside out through the mouth and pushed over the soft parts of the mollusc. The digestive juices from the stomach dissolve

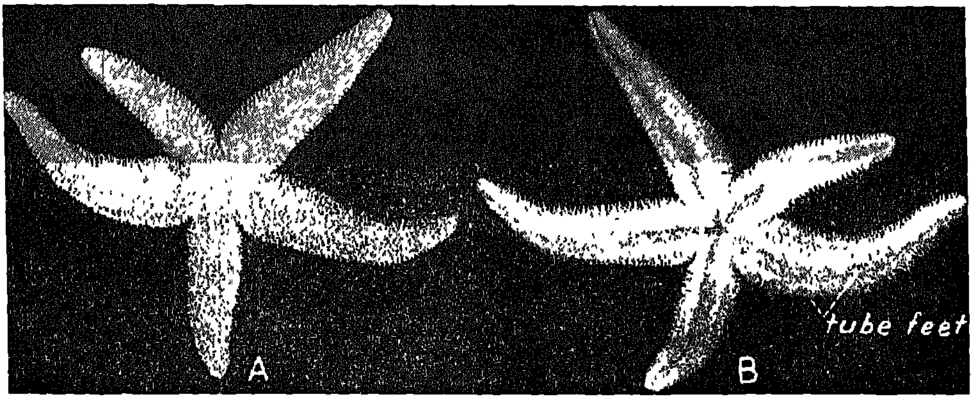

Fig. 37.1. The starfish (*Pentaceros*) It is neither a fish nor a star. A. View of the upper surface. B. View of the lower surface.

the flesh of the mollusc and the digested food is taken in. Starfishes devour pearl oysters and therefore they are weeded out from oyster beds.

The sea urchin (*Echinus*) is found at the bottom of the sea and looks like a spiny ball (Fig. 37.2). The body is enclosed in a shell made up of twenty rows of plates covered with movable spines Five rows of tube feet corresponding to the arms of starfish alternate with areas without tube feet. The mouth with five sharp cutting teeth is situated on the under surface. Sea urchins feed mostly on decaying vegetation and thus act as scavengers.

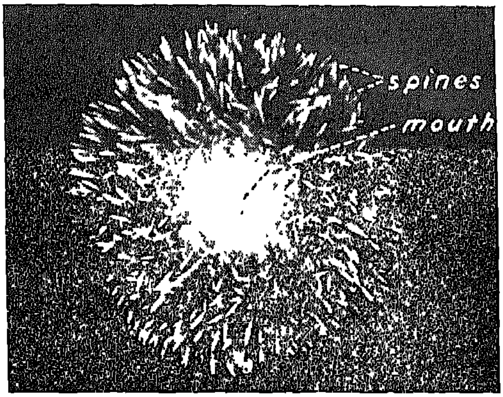

Fig. 37.2. The sea urchin (*Echinus*) Although it appears different from the starfish, its body is made on the same plan. The animal is of the form of a ball covered with spines.

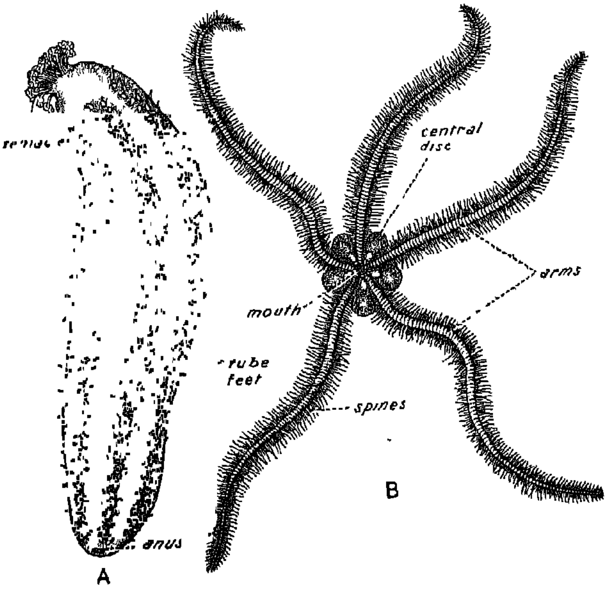

Fig. 37.3. A. The sea cucumber (*Holothuria*). B. The brittle star (*Ophiothrix*) viewed from the oral surface. It is also known as 'serpent star' because of its snake-like appearance and the movement of its flexible arms.

The sea cucumber (*Holothuria*) is a cylindrical soft-bodied animal living in shallow waters. The mouth is situated at one end and the anus at the other (Fig 37.3 A). The brittle star (*Ophiothrix*), also called serpent star, has five long, fragile arms arising from a central disc (Fig 37.3 B) Brittle star is so named because it can readily break off parts of its arms when attacked by enemies. The lost parts are regenerated. A peculiar feature of its digestive system is the absence of the anus so that the indigestible matter is passed out through the mouth itself The feather star (*Antedon*), unlike other echinoderms, remains attached to the bottom of the sea by several root-like processes (Fig 37. 4) or by a single stalk. The arms are branched and the mouth as well as the anus are situated on the upper surface

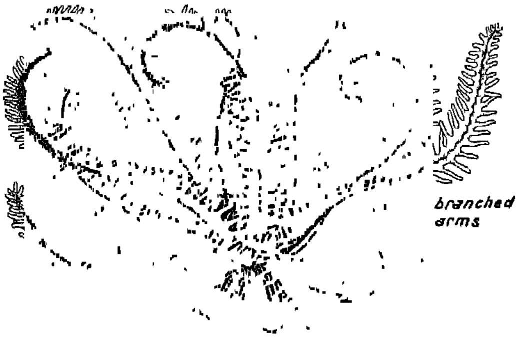

Fig. 37.4. Lateral view of the feather star (*Antedon*). After T J. Parker, W.A Haswell and O Lowenstein, *A Text-Book of Zoology*, Macmillan & Co., Ltd , London, 1957.

SUMMARY

The echinoderms are spiny-skinned marine animals The body is shaped like a star or a ball The starfish is the best known example. It crawls on the sea-floor by means of soft tube feet. It feeds on the soft parts of clams and oysters The stomach is turned inside out to surround and digest the flesh. Starfishes devour pearl oysters and cause great losses. Other common echinoderms are sea urchins, sea cucumbers and brittle stars.

QUESTIONS

1. How do echinoderms differ from other animals ?
2. How does the process of digestion in a starfish differ from or resemble that in other animals ?

FURTHER READING

Buchsbaum, R 1948 *Animals Without Backbones* University of Chicago Press, Chicago

Hanson, E.D. 1961 *Animal Diversity*' Foundations of Modern Biology Series Prentice-Hall, Inc , Englewood Cliffs, New Jersey.

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